POWER

Vol. 46 NEW YORK, JULY 24, 1917 No. 4

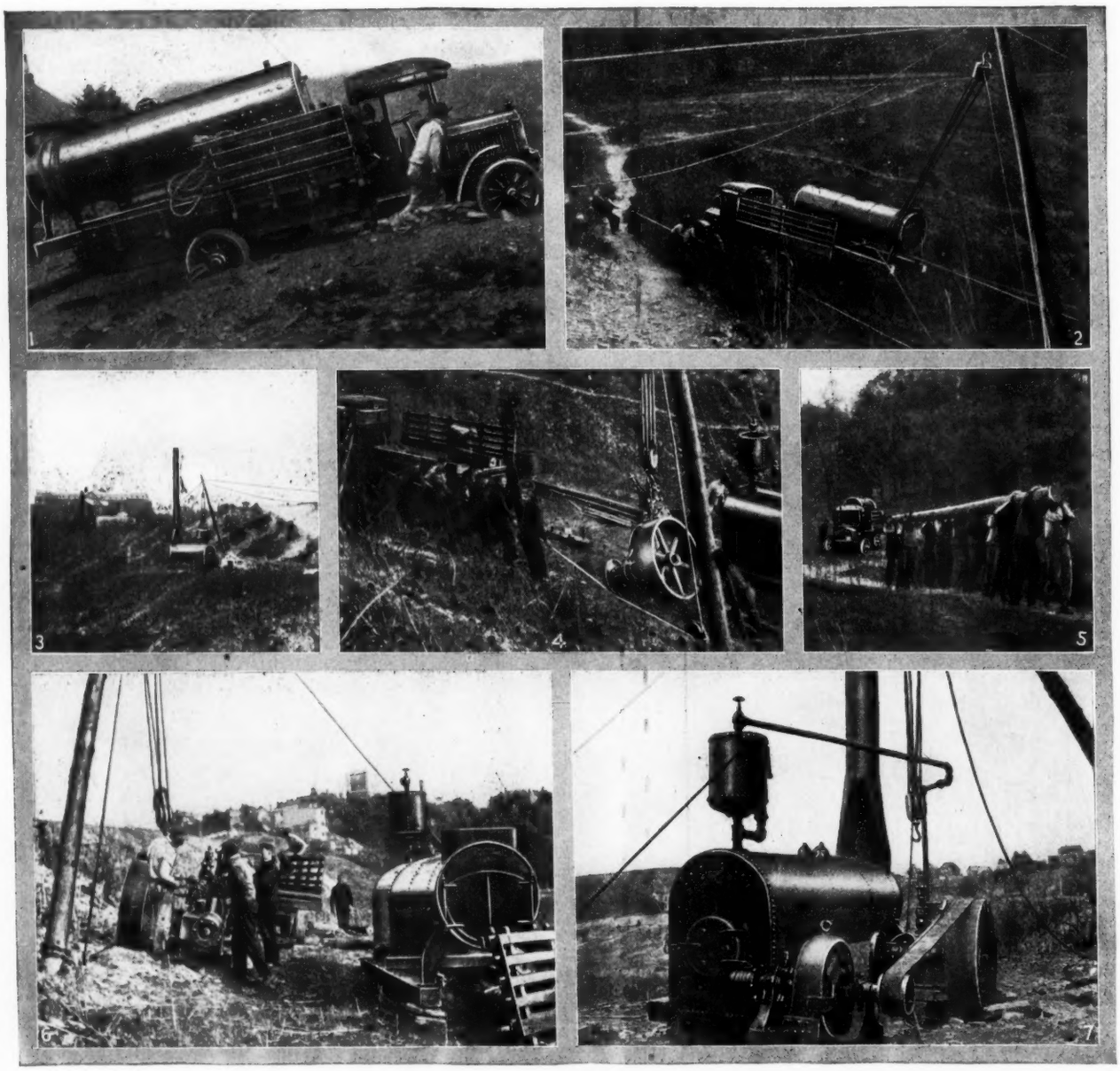
Uncle Sam Views His Plants with Satisfaction

Erecting a Field Power Plant

By H. W. T. COLLINS
Department of Mechanical Engineering, University of Cincinnati

AS A preparedness "stunt," a 40-hp. steam plant was recently transported one mile and erected ready for operation in 15 working hours by a laboratory class of 18 mechanical and electrical coöperative engineering students at the University of Cincinnati. This was a part of the training in military science which for two months has been given under the direction of Major W. E. Etokey, U. S. Engineers Corps. Besides military power-plants, instruction was given in reconnaissance, rigging and tackle, bridge building, road making, fortifications and explosives, all of which would be of value in Government service.

The details of the task were carried out under the command of two students elected for the purpose, who were given only general instructions and on whom rested the responsibility for the success of the project. The problem assigned was to supply current for lighting a tract comprising about four acres, which was designated as a "camp." The plant consisted of a horizontal firebox boiler, mounted on skids, a 10 x 16-in. side-crank engine, a boiler-feed pump, an injector and a cold-well pump. The electrical equipment comprised a generator, switches and instruments, a supply of arc and incandescent lamps and accessories.



FIGS. 1 TO 7. VIEWS OF THE WORK CARRIED OUT BY THE FIELD SQUADS

Fig. 1—Truck and boiler stalled. Fig. 2—Unloading the boiler from the stalled truck. Fig. 3—Power plant sheltered from the "enemy." Fig. 4—Unloading the equipment. Fig. 5—Carrying a gin pole to the plant site. Fig. 6—Handling the engine. Fig. 7—The plant set up

For "military reasons" the location of the plant was kept secret until the day set for the erection. The site selected was an abandoned stone quarry. On a narrow ledge sheltered and concealed from the "enemy" by hills (Fig. 3) the "engineer corps" was directed to set up the plant. Reconnaissance had shown the presence of a spring in a ravine 70 ft. below the level of the camp and about 600 ft. to the rear. This afforded an adequate supply of water, and a nice problem was involved in getting the water to the boiler. The camp site was accessible only by a winding path over rough country. This made the transportation difficult, but the surmounting of obstacles was a part of the game.

About 8 o'clock in the morning a detail of motor trucks arrived, and the equipment, which had been assembled at the university was quickly loaded by a squad assigned for this work. In the meantime another squad was preparing the site. The preliminary duties of the latter group included burying holdfasts or "deadmen" to which the guys of the "gin pole" were to be attached, damming the spring to provide a pool for the water supply and building a temporary roadway.

Transportation Difficulties

This work was hardly completed when word came that the transportation squad was in difficulty. The truck containing the boiler was stalled on a precipitous hillside, and the boiler was threatening to slide off into the road (Fig. 1). Every man was put to work, and a deadman was quickly buried. As the truck and load was very heavy and the manpower limited, it was necessary to arrange three sets of tackle blocks. The first set, a 1¼-in. fivefold tackle, was fastened one block to the truck and the other block to the deadman. The second, a threefold tackle, was made fast to the deadman and the running end of the first tackle, and the third, also threefold, was attached to the running end of the second. The entire party siezed the running end of the third tackle, and by taking up slack and running about 150 feet, moved the truck nearly a foot. The truck wheels were then blocked, the tackle overhauled and the operation repeated until the truck was finally pulled over the hill.

Transportation troubles did not end here, however. Recent rains had so softened the ground that the truck frequently sank to the hubs. In each case it was necessary to jack up the truck and build a road under the wheels. Fortunately quantities of flat rocks were available for this purpose. While part of the men were extricating the truck, others carried the gin pole (Fig. 5) to the plant site, and erected it in readiness for unloading the equipment. The truck finally stalled near the spot which had been selected for the plant, and the boiler was dragged the rest of the way (Fig. 2).

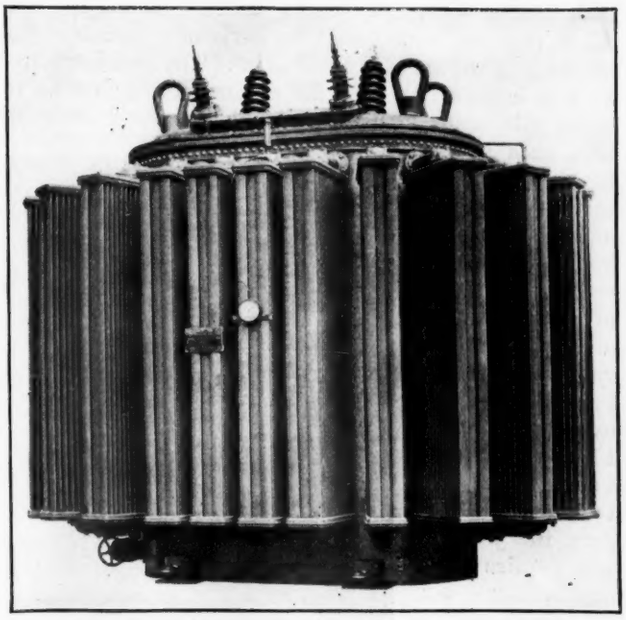
The truck bringing the engine and generator encountered similar difficulties, but having a lighter load, was more easily handled. Figs. 4 and 6 show the method of unloading and handling the engine.

In the meantime the tools, pipe and other supplies had been arriving. A squad of pipe fitters went to work, and a steam pump was set up in the ravine to pump the water from the pool. Steam and water lines were run to the pump, which discharged into the water barrel serving the boiler feeders. An injector was used as a boiler feed, and an auxiliary feed pump was set up with its exhaust heating the feed water. A plentiful supply of pipe and fittings was provided, and all cutting and threading of the pipe was done in the field.

Transportation difficulties occupied the attention of the entire party for the greater part of the day, and darkness fell before the engine was set up. A guard was placed and the work was suspended until daylight. The next day was cold and rainy, and the usual unexpected difficulties were encountered. These did not prevent the rapid completion of the task, however. A pit was dug for the engine flywheel, logs were cut and hewn, then buried for the engine foundation and the engine bolted fast. The generator was then set up (Fig. 7) and a squad detailed as electricians ran wires to the various parts of the camp and prepared the lights. A fire was started in the furnace and steam gotten up while the engine piping was completed. At dusk the engine was started and the lights flashed on. The plant was operated all night, keeping the camp illuminated. It was then dismantled, and the equipment was returned to the university.

Largest Self-Cooled Transformer

Oil-insulated, self-cooled transformers contained in fluted tanks were, until recent years, limited to about 500 kw. capacity, and units larger than this were usually of the oil-insulated, water-cooled or air-cooled type. However, with the development of the outdoor substation there was created a demand for large transformers that would operate in any climate and under all kinds



RADIATOR-TANK TYPE, OUTDOOR TRANSFORMER

of weather conditions without an attendant. This gave new life to the self-cooled oil-insulated type of transformers, and new designs were developed. One of the most marked features of these units was in the construction of the tank, which provided some additional means of cooling the oil. Separate radiators, external tubes connecting the top and bottom of the tank and

usually known as the tubular type of tank, external annular jackets and a large number of vertical external radiators constructed of corrugated steel and connected to the top and bottom of the tank, through which the heated oil from the transformer tank circulates and is cooled, are being used. The result of this development is, the sizes of self-cooled oil-insulated transformers have been increased until they have reached the proportion of the one shown in the illustration. This unit is the world's largest self-cooled transformer and was built by the General Electric Co., Schenectady, N. Y. Six of these units have been constructed for the Carnegie Steel Co. They are single-phase 25 cycle 8000 kv.-a. each, giving a total capacity of 48,000 kv.-a. and step the voltage down from 44,000 to 6600.

The unique feature of these transformers is the construction of the external radiators, which consist of a number of vertical flattened tubes rigidly welded into headers which are flanged for bolting to the tank. The cast-iron elbows between the tank and the radiators are provided with machined surfaces where they are bolted to the flanges of the tank and the radiator. The twenty-four radiators give a radiating surface of 800,000 sq.in. As the oil is heated in the containing tank, it rises to the top of the tank and out into the radiators, while the cool oil flows in at the bottom, thus producing automatic circulation of the oil through the radiators.

All seams and joints in the tank and radiators are welded to prevent oil leaking. The radiators are self-draining and have no pockets, preventing the accumulation of air at the top or moisture and sediment at the bottom. These refinements of the radiator type of transformer can materially increase the kv.-a. rating of the self-cooled unit and make possible a wider latitude in their field of application.

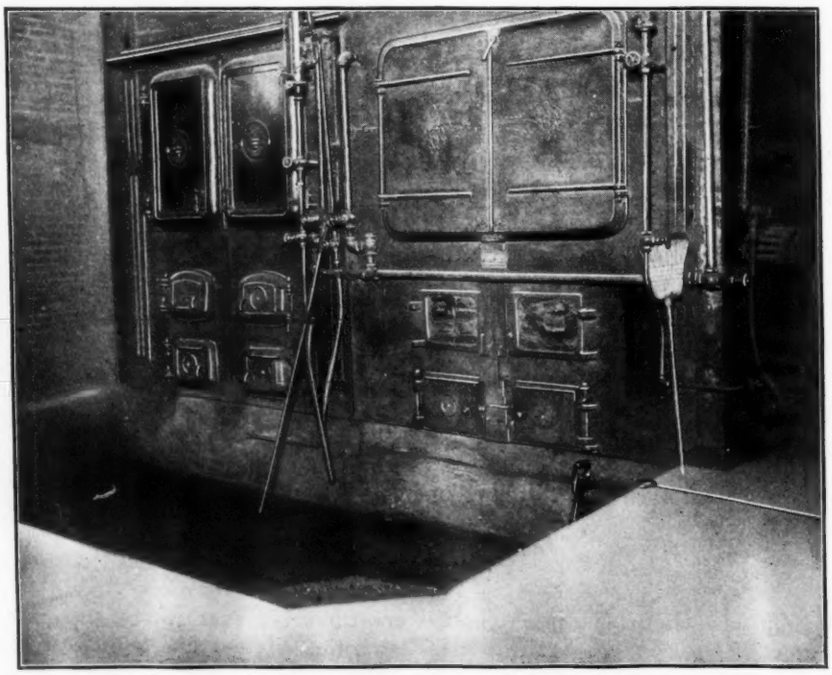
The transformer winding is of the circular-disk-coil interleaved type mounted on the center leg of a three-legged core.

Small Central Station Operation

BY ARTHUR GROESBECK
Superintendent, Water and Electric Department, McPherson, Kan.

Some figures showing the performance of a small central station after leaks had been stopped and the design of the furnace changed. Politics were eliminated, much to the benefit of the plant.

AT THIS time of high prices of fuel it is necessary for power-plant men to carefully guard the coal pile and ways must be devised to increase the efficiency of the average small plant. The manager must work in conjunction with his engineers and firemen to attain this result. There are many ways to accomplish this, such as the bonus system for certain percentages of CO_2 or a bonus for a coal record per unit of output under a predetermined value, etc. It has been the writer's experience that these methods tend to place temptation before the firemen and require more supervision on the part of the chief engineer. A combination of these methods with a service bonus has all the advantages and none of the disadvantages of the two. The first requisite, of necessity, is that the fireman shall take an interest in his work. By a series of tests made with the regular operating force a certain record can be made and established as the standard. As the firemen themselves have made this standard, they know that they can at least always equal it and will be expected to do so. The bonuses should be paid according to the length of service—a certain percentage of the yearly salary for one year, a certain larger percentage for two years, etc. Then give every man in the plant a vacation every year on full pay.



THE GRATES OF THESE BOILERS ARE SO LOW THAT THE ASHPIT DOORS ARE USED FOR FIRING

One of the most difficult problems with which the manager of the small plant has to contend is the economical production of power, and it is the aim of this article to show what has been accomplished in a typical small central station. The power equipment includes two 72-in. by 18-ft. return-tubular boilers equipped with forced-draft slack burners. There are also one 75-kv.-a. 2300-volt generator belted to a 14 x 36-in. simple, noncondensing Corliss engine, speed 100 r.p.m., and a 175-kv.-a. 2300-volt generator belted to a 16 x 36-in.

simple, noncondensing Corliss engine, speed 100 r.p.m. There are the necessary feed pumps, heater, two deep-well pumps, both motor-driven by a belt and jackshaft, besides other miscellaneous apparatus.

The illustration shows how a change in the furnace construction led to a reduction in coal consumption. A pit two feet deep was dug in front of the boilers, and the grates were lowered so that the original ashpit doors are now used for the firing doors. The distance from the grates to the boiler shell is 60 in. Tests made before and after the change show that the saving in fuel amounts to over 10 per cent. with nearly smokeless combustion. The fires are cleaned once on each eight-hour shift and the ashes are taken out through the fire-doors. About once every six months it is necessary to clean out under the grates and to do this a couple of grate bars are taken out and the soot shoveled back into the combustion chamber and then out through the rear of the boiler setting.

The table gives the data and results of a test made of the plant to determine the actual cost of production.

DATA AND RESULTS OF EVAPORATION TEST

Date	Oct. 24, 1916
Number and kinds of boilers	One 150 hp. return tubular
Kind of furnace	Economy forced draft
Grate area, sq.ft.	36
Water-heating surface, sq.ft.	1500
Ratio of water-heating surface to grate surface	41.7
Duration, hours	24
Kind and size of coal	Slack, Southern Kan.
Average Pressures, Temperatures, etc.	
Steam pressure by gage, lb.	110
Temperature of feed water, deg. F.	162
Temperature of gases leaving boiler, deg. F.	481
Moisture in steam (assumed), per cent	2
Hourly Quantities and Rates	
Dry coal consumed per hour, lb.	374.0
Dry coal per square foot of grate surface per hour, lb.	10.38
Water evaporated per hour, corrected for moisture, lb.	2,969
Equivalent evaporation per hour from and at 212 deg. F., lb.	3,245
Equivalent evaporation per hour from and at 212 deg. per square foot of waterheating surface, lb.	2.16
Proximate Analysis of Coal As Fired	Per Cent.
Fixed carbon	50.14
Volatile matter	31.13
Moisture	2.14
Ash	16.59
Sulphur separately determined	4.46
Capacity and Economy Results	
Evaporation per hour from and at 212 deg. F., lb.	3,245
Boiler horsepower developed	94.1
Rated capacity per hour from and at 212 deg. F., lb.	5,175
Rated boiler horsepower	150
Rated capacity developed, per cent	62.7
Water fed per pound of coal as fired, lb.	7.93
Water evaporated per pound of dry coal, lb.	7.94
Equivalent evaporation per pound of coal as fired, lb.	8.49
Equivalent evaporation per pound of dry coal, lb.	8.68
Calorific Value and Efficiency	
Calorific value of coal as fired, B.t.u.	12,440
Calorific value of coal as dry coal, B.t.u.	12,712
Efficiency of boiler and furnace, per cent	66.2
Cost of Evaporation	
Cost per ton of coal on boiler-room floor	$2.60
Fuel cost per thousand pounds of water evaporated from and at 212 deg.	.1532
Analysis of Dry Gases by Volume	Per Cent.
Carbon dioxide, CO_2	12.4
Oxygen, O_2	6.5
Carbon Monoxide, CO (last pass)	0.0
Nitrogen by difference	81.1
Air excess	43.9
Summary of Generating Costs	
Date	Oct. 5-6, 1916
Time	24 hours
Pounds of coal	9,172
M pounds of water	72.71
Kw.-hr. output	1,474
Coal per kilowatt-hour, lb.	6.22
Water per kilowatt-hour, lb	49.33
Fuel cost	$11.92
Labor	8.55
Oil, waste, packing	.23
Boiler compound	.10
Boiler water @ 5c. per M gal.	.37
Plant expense	.46
Repairs	1.57
Total cost	$23.20
Fuel cost per kilowatt-hour, cents	.8087
Total cost per kilowatt-hour, cents	1.5739

The coal was weighed on platform scales which were frequently checked by means of standard weights. The water was weighed on platform scales which were also frequently checked. The feed water was pumped from the heater into tanks on the scales, discharged into a receiving tank and then pumped to the boiler. The temperature of the feed water averaged about 165 deg. F. during the test, but under normal operating conditions would average about 190 deg. Samples of flue gas were taken frequently and analyzed and the temperature of the gases leaving the boiler was taken every 30 min. The moisture in the steam was assumed to be 2 per cent. The firing conditions were good, and the combustion was good as shown by the analysis of the gases. The labor cost is on the basis of one man at $75 per month, one at $65 and two at $60. The oil, waste, packing, boiler compound, plant expense and repairs have been proportioned on the cost for the first nine months of 1916.

The load factor is good, as a 50-hp. motor is cut off during the peak and started as the load begins to drop off and is run all night. This, with the street lights, makes a fair load and for the smaller machine is nearly full load. The maximum hourly output for Oct. 5 was 122 kw-hr. between 7 and 8 p.m., and the maximum demand load factor was 50.4 per cent.

In order to attain these results, it was first necessary to take the department entirely out of politics.

The next step in the attack on the high fuel cost was an inventory of the operating conditions of the plant. Were the boilers clean? Were the boiler settings tight and the furnaces in good condition? Were the firemen using the proper draft and were they using the dampers instead of the ashpit doors, thus reducing excess air? Were they using the best method of firing? Were the blow-off valves tight and used properly? Was the feed-water heater clean and giving maximum temperature? Were the combustion chambers clean and the tubes free from soot? Were all exposed steam lines covered? Were the engines and pumps operating at maximum economy? Were the valves properly set?

The one word "no" answered all these questions. After removing the scale, some of which was over half an inch thick, it was necessary to restub the tubes, but this item of expense was small compared with the cost of fuel that had been wasted owing to this scale. After cleaning the boilers and heater a cheap chemical was fed continuously into the heater and the boilers today, after three years of operation, are free from scale. The boiler settings were in such shape that the inrush of cold air would draw out the flame of a candle at nearly every point where it was applied. The settings were repaired and painted with two coats of asphalt, which has proved to be an excellent remedy for leaky settings.

The firemen were instructed as to the best method of firing and the proper use of the dampers. It is very hard to induce a fireman to change his way of firing, but this was accomplished by running tests with different methods and giving the fireman the results of the tests. Pipe covering was purchased and all the steam lines covered. We also purchased an indicator and by using it regularly are enabled to keep the valves properly set. A recording steam gage gives constant steam pressure and a voltage regulator gives constant voltage. After making these changes, one boiler easily carried the load where previously it had required two.

Capacities of Transformers for Induction Motors

By G. P. ROUX
Consulting Engineer, Philadelphia, Penn.

The characteristics of the distributing transformer and squirrel-cage induction motor are discussed, showing how to determine the proper capacity of transformers for different size induction motors.

IN INDUSTRIAL power installations supplied from transformers connected to distribution lines, the question of capacity to be provided arises almost daily and no fixed rules, other than mere speculative estimates, are available for the solution of these practical problems. It is therefore of interest to study and discuss this question in order to more conveniently meet the requirements of each application. Inasmuch as nearly 90 per cent. of the induction motors in use are of the squirrel-cage type, its performances and also that of the standard distribution transformer will be analyzed, taking as a typical example an installation with a 30-hp. 220-volt three-phase 60-cycle 900-r.p.m. constant-speed induction motor with a starting compensator.

To supply power to moderate-sized industrial installations, ordinary standard distribution transformers are generally used, the power ratings of which are given in full-load kilovolt-amperes. The voltage rating of the primary is adapted to some standard distribution-line voltage, commonly 2200 volts, and the ratio of voltage transformation is 20 to 1, 10 to 1 or 5 to 1 according to the requirements.

Voltage at Transformer Terminals

The actual line voltage is, as a rule, somewhat different from the standard line voltage and varies according to the line losses, which are in most cases partly compensated for at the power house or substation by boosting the voltage of the outgoing lines. The secondary voltage of the transformers connected to distribution lines therefore varies from place to place and throughout the day according to the uncompensated line drop. Sometimes it is possible to give the secondary voltage a further adjustment when the transformers are provided with regulation taps, a practice that is gradually being abandoned by many manufacturers because of complications and difficulties in the manufacture of the apparatus which increase its cost and decrease its reliability.

The kilovolt-ampere rating of a transformer does not necessarily represent its effective rating in kilowatts. The latter will vary according to the power factor at which the apparatus operates, but the kilovolt-ampere load supplied by the transformer will govern its operating characteristics such as heating, efficiency and regulation, all of which is shown in Fig. 1, for a standard 10-kv.-a. 60-cycle distributing transformer, having a 2200-volt primary and 110- and 220-volt secondary.

At constant kilovolt-ampere output, normal primary voltage and frequency, the available kilowatt output decreases in proportion to the power factor, the efficiency slightly decreases owing to the reduction in effective capacity; hence, the input slightly increases. The regulation, or percentage reduction of secondary voltage, increases as the power factor decreases.

The full-load kilovolt-ampere rating of a transformer is not the maximum load that the apparatus can safely carry, which depends on its internal losses and details of construction affecting its cooling capacity. Most of the standard transformers are designed and built to carry 125 per cent. full load for two hours and 150 per cent. full load for one hour without injurious heating. However, if the overload is applied after a long period of operation at full load, the heat developed may become injurious to the insulation and to the oil, if maintained for a sufficient length of time and repeatedly. The overload limitations of a transformer are merely a matter of heating and heat dissipation. In the absence of means to determine the exact temperature of the windings, it follows that for safety of operation the amount of overload and the length of time a transformer can be operated above its normal rating must be

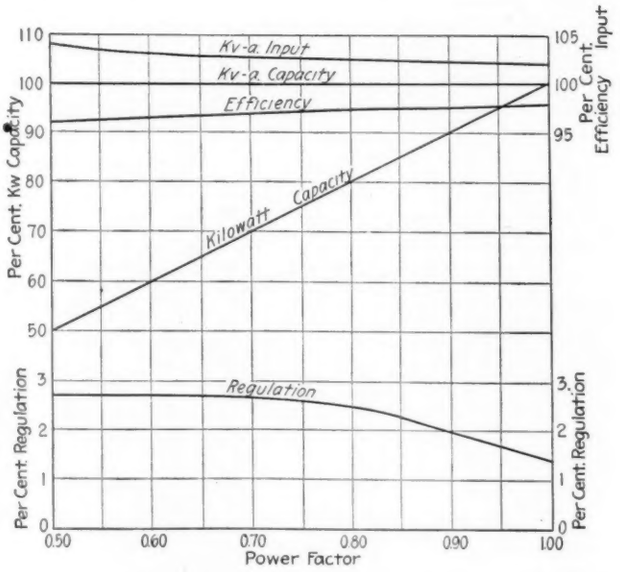


FIG. 1. PERFORMANCE OF 10-KV.-A. TRANSFORMER AT CONSTANT KV.-A. AND DIFFERENT POWER FACTORS

limited to the periods and overload values already given, in order not to exceed a temperature rise in the copper and iron of more than 65 deg. C. above that of the surrounding air, taken for reference at 40 deg. C., as recommended in the Standardization Rules of the A. I. E. E.

A typical diagram of the heating performance of the standard 60-cycle distribution transformer is shown in Fig. 2. The oil never reaches the temperature attained by the copper windings or core, therefore thermometer readings of the temperature of the oil do not give the temperature of the windings. It will be noticed

from Fig. 2 that after a certain lapse of time the temperatures become constant for a constant load.

While the curves of Fig. 2 represent average conditions for indoor transformers operating at altitudes up to 3000 ft., and with a ratio by weight of oil to core of 1 to 5, the results vary according to the characteristics of each make of transformer, the quality and viscosity of the oil and atmospheric conditions. The outdoor transformer has greater cooling facilities than the

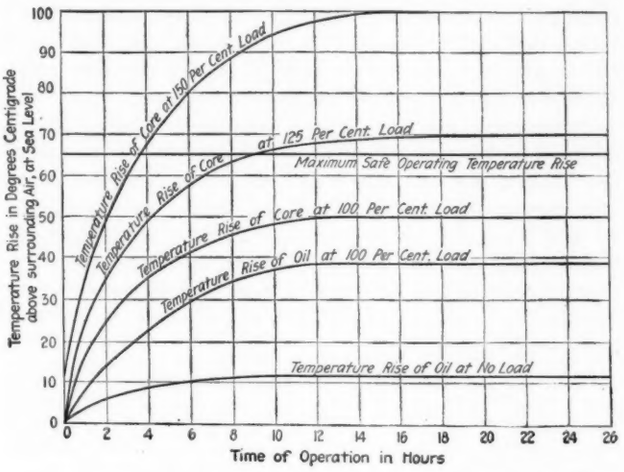

Temperature Rise in Degrees Centigrade above surrounding Air at Sea Level
Temperature Rise of Core at 150 Per Cent. Load
Temperature Rise of Core at 125 Per Cent. Load
Maximum Safe Operating Temperature Rise
Temperature Rise of Core at 100 Per Cent. Load
Temperature Rise of Oil at 100 Per Cent. Load
Temperature Rise of Oil at No Load
Time of Operation in Hours

FIG. 2. TEMPERATURE RISE OF OIL AND CORE OF 10-KV.-A. TRANSFORMER

indoor type. The limiting temperature rise being based on a surrounding temperature of reference of 40 deg. C., this allows a final maximum temperature of 105 deg. C., but if the ambient temperature is less than 40 deg. C. (104 deg. F.)—as for instance, in the winter—then the transformer can be subjected to a greater overload, as long as the final temperature does not exceed the maximum of 105 deg. C. (221 deg. F.).

With a diagram similar to the one shown in Fig. 2 and referring to a particular type of transformer, it is possible to determine its heating characteristic and the amount of overload that it can safely carry for any period of time.

Variation in the voltage and frequency of the supply line affects the operation of the transformer as summarized here:

	Exciting Current	Regulation	Power Factor
Low voltage	Decreased	Worse	Higher
High voltage	Increased	Improved	Lower
Low frequency	Increased	Improved	Lower
High frequency	Decreased	Worse	Higher

The constant-speed squirrel-cage polyphase induction motor represents the type most generally used in alternating-current power installations. An induction motor is in many ways similar in its operation to a transformer. It consists of a system of polyphase primary windings producing a rotating magnetic field which is completed through the rotor, or secondary, and provided with short-circuited windings. The conductors, being cut by the revolving magnetic flux, are caused to move and rotate at the same synchronous speed (less the slip) as the primary system.

While the mechanical characteristics of an induction motor compare very closely to those of a shunt-wound direct-current motor, its electric and magnetic performances resemble those of a transformer with an air gap between the primary and secondary. This causes a considerably greater magnetizing current and leakage reactance, which in turn decreases the power factor.

An induction motor, like a transformer, can be designed with its characteristics so adjusted as to meet a great variety of requirements. The improvement of one characteristic is, however, obtained to the detriment of another, and unless intended for special duties, the polyphase induction motors manufactured in this country have the average performances shown in Fig. 3. These performances are naturally subject to slight departures according to the make, type, speed and voltage of the motor.

When standing still the induction motor is like a transformer with its secondary short-circuited; therefore it takes a considerable current when connected to a source of voltage. The value of this current depends on the applied voltage and impedance of the motor. Reducing the voltage or increasing the impedance reduces the value of the starting current. This is a very important item, as it affects the source of supply of power and the operation of other apparatus connected thereto. The starting current taken by an induction motor is equal to $\frac{E}{Z}$, E being the applied voltage and Z the total impedance of the motor. The current rises rapidly upon closing the circuit to start the motor and falls gradually as the speed increases and becomes finally steady when approximate synchronous speed is reached,

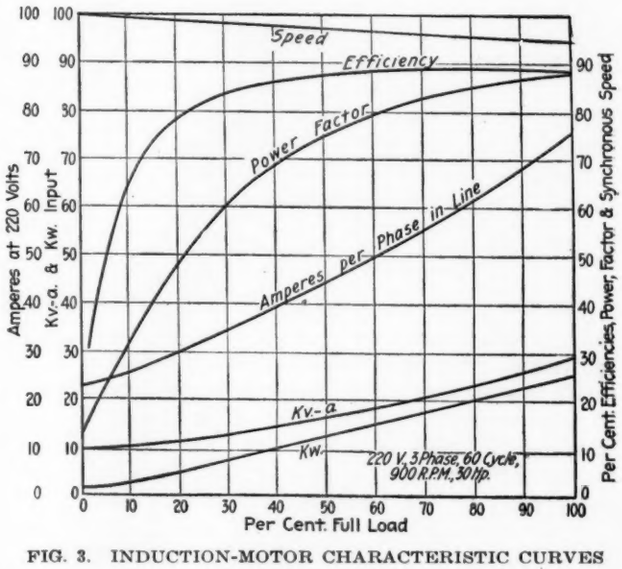


FIG. 3. INDUCTION-MOTOR CHARACTERISTIC CURVES

rising subsequently as the mechanical load is increased. The starting torque is directly proportional to the square of the impressed voltage and the secondary or rotor resistance, and inversely to the impedance.

In Fig. 4 are shown graphically the starting performances of a 30-hp. 220-volt three-phase motor, from standstill to full synchronous speed, when started by means of a starting compensator connected on different voltage taps. The dotted curves indicate the values of the torque for the different percentages of line voltage. Both the starting current and the starting torque depend on the connections made at the auto-starter, the rotor resistance remaining unvaried. The object of the

auto-starter is to reduce the line voltage and increase the current by auto-transformation. This apparatus generally consists of a number of single-phase windings connected either open-delta or star and provided with taps giving different voltages below that of the line. The coils are designed for intermittent operation only and made to carry a current density considerably greater than in an ordinary auto-transformer in order to reduce their size

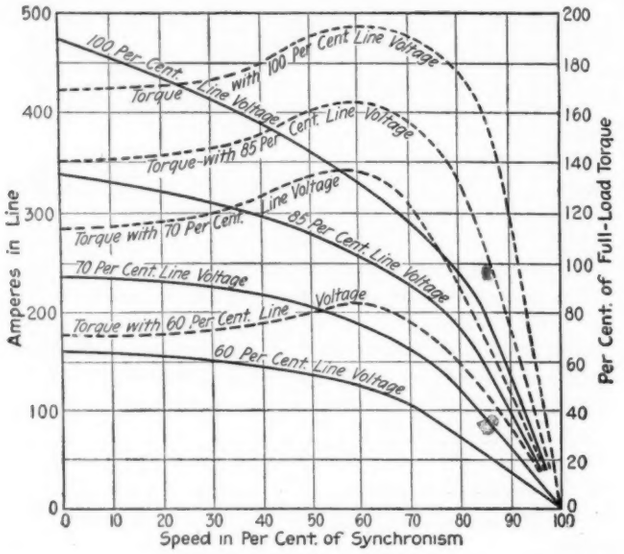

100 Per Cent. Line Voltage
Torque with 100 Per Cent. Line Voltage
Torque with 85 Per Cent. Line Voltage
Torque with 70 Per Cent. Line Voltage
Torque with 60 Per Cent. Line Voltage
85 Per Cent. Line Voltage
70 Per Cent. Line Voltage
60 Per Cent. Line Voltage
Amperes in Line
Per Cent. of Full-Load Torque
Speed in Per Cent. of Synchronism

FIG. 4. STARTING-SPEED TORQUE CURVE OF 30-HP. THREE-PHASE MOTOR ON FOUR DIFFERENT VOLTAGES

to a minimum, which is permissible, as they do not remain in the circuit after the motor is started.

It is general practice to start a squirrel-cage motor on one low-voltage tap on the compensator; after the motor reaches near synchronous speed, it is thrown on full-line voltage. The ratio of starting voltage to line current is given in the following table:

Line voltage	100	100	100	100	100	100	100
Per cent. tap and voltage at motor	40	50	58	65	70	80	85
Per cent. full-voltage starting current	16	25	34	42	50	65	72

The performance of a 30-hp. motor from standstill to full synchronous speed, against a starting torque equivalent to two-third full-load torque, is shown in Fig. 5. It is seen that at the moment of starting 61 kv.-a. is taken by the motor. The kilovolt-ampere input, however, gradually decreases and then rapidly falls as the speed increases, to a value for full speed and no load represented by the exciting current plus the friction and windage losses, or about 9 kv.-a., but with a very low power factor. The power factor improves as the mechanical load is applied and reaches about 0.87 at full load, as shown in Fig. 3.

Assuming that three 10-kv.-a. transformers have been provided to supply power to the motor in question, it will be seen from Fig. 5, that for starting duty they will be subjected to a load of 203 per cent. their full rated capacity. However, this overload will not remain for more than from one-fourth to one-half a minute each time the motor is started, the load on the transformers thereafter increasing from 9 kv.-a. at no load to 29 kv.-a. at full-rated load.

Under normal starting and operating conditions the kilovolt-ampere load drawn from the transformers in question and the secondary voltage are shown in Fig. 6. Both curves indicate that it is safe to provide in such cases transformer capacity at the rate of one kilovolt-ampere for each horsepower of rated capacity of the motor, even if the motor is to operate occasionally with overload, provided the overloading periods do not exceed the heating guarantees of the transformers, as shown in Fig. 2.

In installations where more than one motor is supplied from the same bank of transformers, an investigation of the duties of the motors must be made to determine the demand factor, or ratio of maximum combined demand to transformer capacity, together with the length of time of maximum demand, and the transformer capacity provided accordingly.

Taking, for instance, an installation consisting of one 30-hp., one 10- and two 5-hp. motors, not to be started at the same time, and normally operating with an average combined demand of 50 per cent.; assuming the 30- and 5-hp. motors to operate at 125-per cent. load two hours a day and the 10-hp. motor to start and stop frequently, and a fairly constant supply voltage and frequency, the combined operating conditions can be analyzed and tabulated as follows:

KILOVOLT-AMPERE REQUIREMENTS

		— Starting Periods —				— Operating Periods —		
Motor	Full-Load Rating	1	2	3	4	Normal	Overload	Overload and Starting
1–30 hp....	30	60	9	9	9	15.0	37.5	37.5
1–10 hp....	10	0	20	3	3	5.0	5.0	20.0
1– 5 hp....	5	0	0	15	1.5	2.5	6.25	6.25
1– 5 hp....	5	0	0	0	15	2.5	6.25	6.25
Total kv.-a.	50	60	29	27	28.5	25.0	55.00	70.00

The maximum instantaneous load is 70 kv.-a., the maximum two-hour load is 55 kv.-a. and the normal load

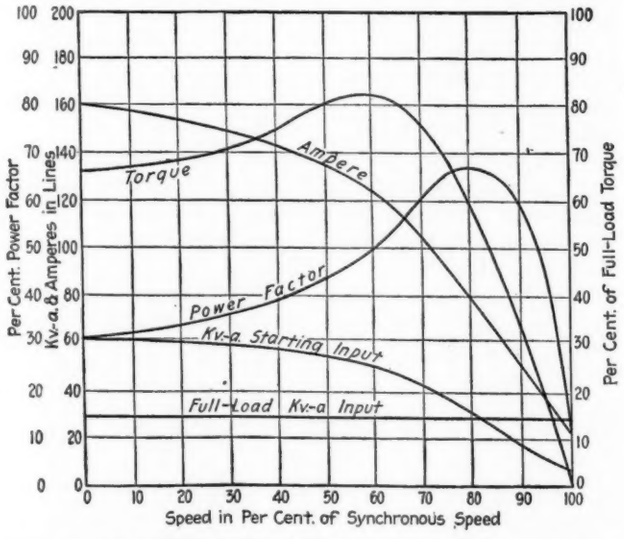


FIG. 5. STARTING CHARACTERISTICS OF 30-HP. INDUCTION MOTOR AT 58 PER CENT. NORMAL VOLTAGE

is 25 kv.-a. only. The maximum starting load is 60 kv.-a.

Three 15-kv.-a. transformers, or a total of 45-kv.-a. transformer capacity, would supply this installation, carrying a load of $\frac{25 \times 100}{45}$ or 55 per cent. under average conditions, $\frac{55 \times 100}{45}$ or 121 per cent. for two hours at time of overload and $\frac{70 \times 100}{45}$ or 155 per cent. at times of overload during the brief but frequent periods

of starting the 10-hp. motor. The temperature rise of the transformers under the worst condition would not exceed 65 deg. C. The demand ratio or capacity of transformer to be provided in the case cited is therefore $\frac{45 \times 100}{50}$ or 90 per cent. of the horsepower rating of the installation.

Knowing the torque t required to start a certain load and the full-voltage starting torque of the motor T, and also the line voltage E, the voltage E' necessary to start the motor is

$$E = E\sqrt{\frac{t}{T}}$$

For instance, if the starting torque T of a 30-hp. motor at full voltage is twice its full-load torque, the line voltage, E, 220 and the torque t required to start

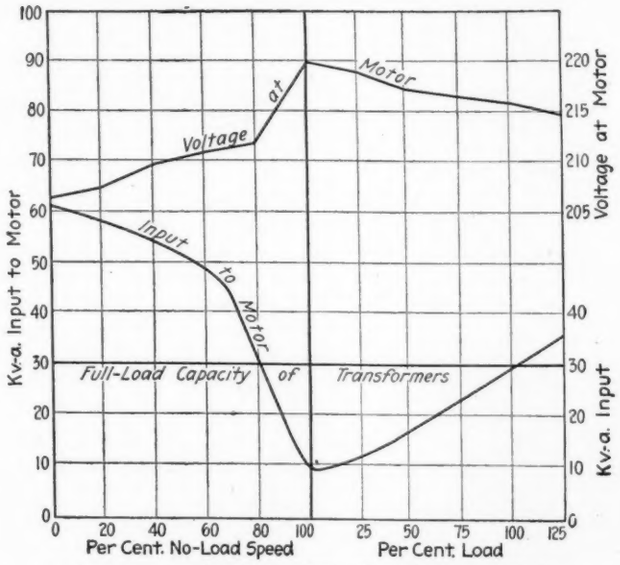


FIG. 6. STARTING AND OPERATING KV.-A. REQUIREMENTS OF 30-HP. MOTOR

the motor with its connected load equal to only 66 per cent. of the full-load torque, the starting voltage necessary to develop the required torque is

$$E' = 220\sqrt{\frac{0.66}{2}} = 220 \times 0.575 = 126 \text{ volts}$$

that is, sufficient torque will be developed by connecting the motor to 60-per cent. taps of the auto-starter, and the line current is reduced to about 36 per cent. the full line-voltage starting current.

Where the starting torque required by the motor to start its connected load (which should be reduced to the minimum consistent with the circumstances) cannot be conveniently ascertained, the motor can be connected first to the lowest tap of the starting compensator. If insufficient torque is developed on that tap, the next higher one can be tried until the right tap is found.

In installations requiring motors to start with an appreciable load, it is preferable to use the slip-ring motor, which is provided with a wound rotor having its winding connected to a set of collector rings, thus permitting increasing the resistance of the rotor for starting duties. The effect is to decrease the starting current while increasing the starting torque and to bring the motor under load to speed without excessive strain on the transformers and supply line.

Variations of voltage and frequency affect all induction motors; their performances vary as follows:

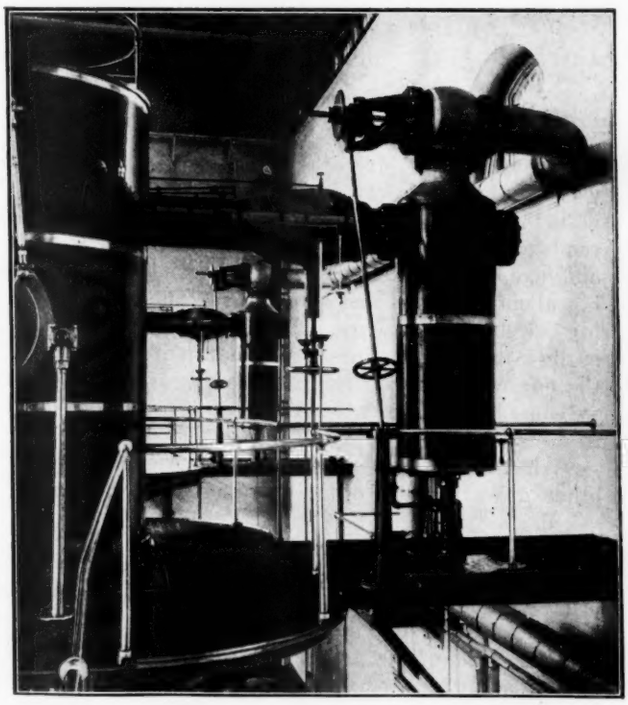
	Torque	Slip	Power factor	Efficiency
Low voltage	Decreased	Increased	Increased	May slightly
High voltage	Increased	Decreased	Decreased	Increase
Low frequency	Increased	No change	Decreased	or
High frequency	Decreased	No change	Increased	Decrease

In general, slight variations of either voltage or frequency are in most cases not objectionable, provided, however, these variations do not exceed 10 per cent. and occur in opposite directions; that is to say, a lower voltage should coincide with a lower and not with a higher frequency and vice versa, otherwise the effects mentioned in the table would be cumulative instead of practically compensating each other. However, a variation in voltage of 10 per cent., or in frequency of 5 per cent., is not desirable for the successful operation of either transformers or motors in any installation.

Operating Valve with Safety

BY H. F. GAUSS

Serious and expensive accidents can often be avoided and injury to operators prevented by arranging apparatus in power plants so that it is accessible and can be operated without the necessity of undue precaution on the part of the workman to avoid slipping or falling. As originally installed, the angle stop valves on two 15,000,000-gal. triple-expansion engines in the Baden Pumping Station of the St. Louis Water Division were located above the steam separators and about ten feet



GEARED VALVE BONNET WITH EXTENSION STEM

above the top gallery around the engine. The gallery under the valve was narrow, and should the ladder on which a man must stand to close or open the valves, slip, the operator would be in danger of falling about forty feet into the pump pit below. To eliminate this dangerous condition the special geared valve bonnet shown was put on with a long stem, the lower end ending in a ball carried in a cast-iron floor stand.

Tom Hunter, Hoisting Engineer

By WARREN O. ROGERS

We find that steam-driven units have been changed over to motor rope drive at one mine, and Hunter explains the type of motor and also the difference between the American and European systems of rope drive. We find another type of motor-driven skip hoist and later on inspect a steel-concrete ore-loading pier having a storage capacity of 50,000 tons of ore and containing 200 pockets, each of 250 tons capacity. Six ore boats can be loaded at one time.

DURING the night the rain ceased, and the next morning the sun shone brightly. After an early breakfast, Hunter and I took a train for Gwinn, where there were several iron mines. The town is neatly laid out and is considered the model mining settlement of the district. One of the features is a clubhouse that was built by the Cleveland-Cliffs Co. in 1909. It contains shower baths, swimming pool, bowling alley, billiard room, library, smoking room, gymnasium and classrooms. The club dues are but 25c. per month. It is open to men and boys, women and girls, although the latter do not have all the privileges that the men and boys enjoy. The first mine visited was the Princeton.

"Well, what do you know about that?" said Hunter as we entered the engine room.

"Know about what?" I asked, wondering what Hunter was talking about.

"Why, here is a steam-compressor machine driven by a motor and rope drive." See Fig. 1. "The machine was, as you see, a cross-compound steam and air unit, with the air cylinders next to the crank, but they have removed the steam pistons, disengaged the valve gear and made the flywheel into a driven pulley. She is making about 75 r.p.m. and according to the gage is carrying 80 lb. air pressure. That is about what is generally carried for mine use. That motor just outside the engine room is driving this unit, and I noticed as we came in that it has the American type of rope drive." See Fig. 2.

"What is the difference between an American and any other drive? What other drive is there, anyway?" I asked.

"I'll answer your last question first," rejoined Hunter as we descended to the motor room. "The other system is the European. The difference is that the American system consists of one rope that is passed over the rims of the driving and driven pulley and also over idler pulleys, one of which is weighted and slides on a track. That is so it can take up any slack in the rope. The European system consists of a number of single ropes each independent of the others and naturally of different tension. If one rope breaks, the others can carry the load. If the rope of the American system breaks, the unit it is driving is down and out."

"What kind of a motor is that," I asked, pointing to the one that was used in driving the compressor. "It looks a good deal like some of the others we have run up against."

"That is a synchronous motor with a belt-driven exciter. The rotor is the same as that used in an alternating-current generator, with a squirrel-cage winding in the polefaces. The squirrel-cage winding serves as an induction-motor secondary during starting. This type of motor is started by giving it a reduced alternating-current voltage directly to the stator winding, which may be anywhere from 50 to 75 per cent. of the normal voltage. When an individual exciter is used, as in this case, the motor field is left connected across the exciter armature while starting. If the motor is excited from an exciting busbar, a double-throw field switch is used for short-circuiting the fields while starting. The motor operates on 2200 volts at 257 r.p.m. and is rated at 625 hp."

Another Electrified Mine

Near-by was another mine shaft, only 300 ft. deep. The hoist, originally operated by steam, had been changed over to a motor drive. A flange coupling had been bolted to one of the engine crank disks and an extension shaft fitted to the coupling. At the outer end of the extension shaft was a straight faced gear that meshed with a similar gear on a jackshaft. The jackshaft also carried a herringbone gear that meshed with a pinion on the motor shaft. The gearing was inclosed in a gear box. The arrangement of the motor and drive is shown in Fig. 4. The induction motor was of 150 hp. and ran at 435 r.p.m. at full speed.

"That is another instance of the motor kicking the steam engine out of the back door," remarked Hunter, as I packed up my camera. "There is no use in burning coal in a number of isolated boiler plants, when the electrical energy can be generated by one large steam plant or by a hydro-electric station."

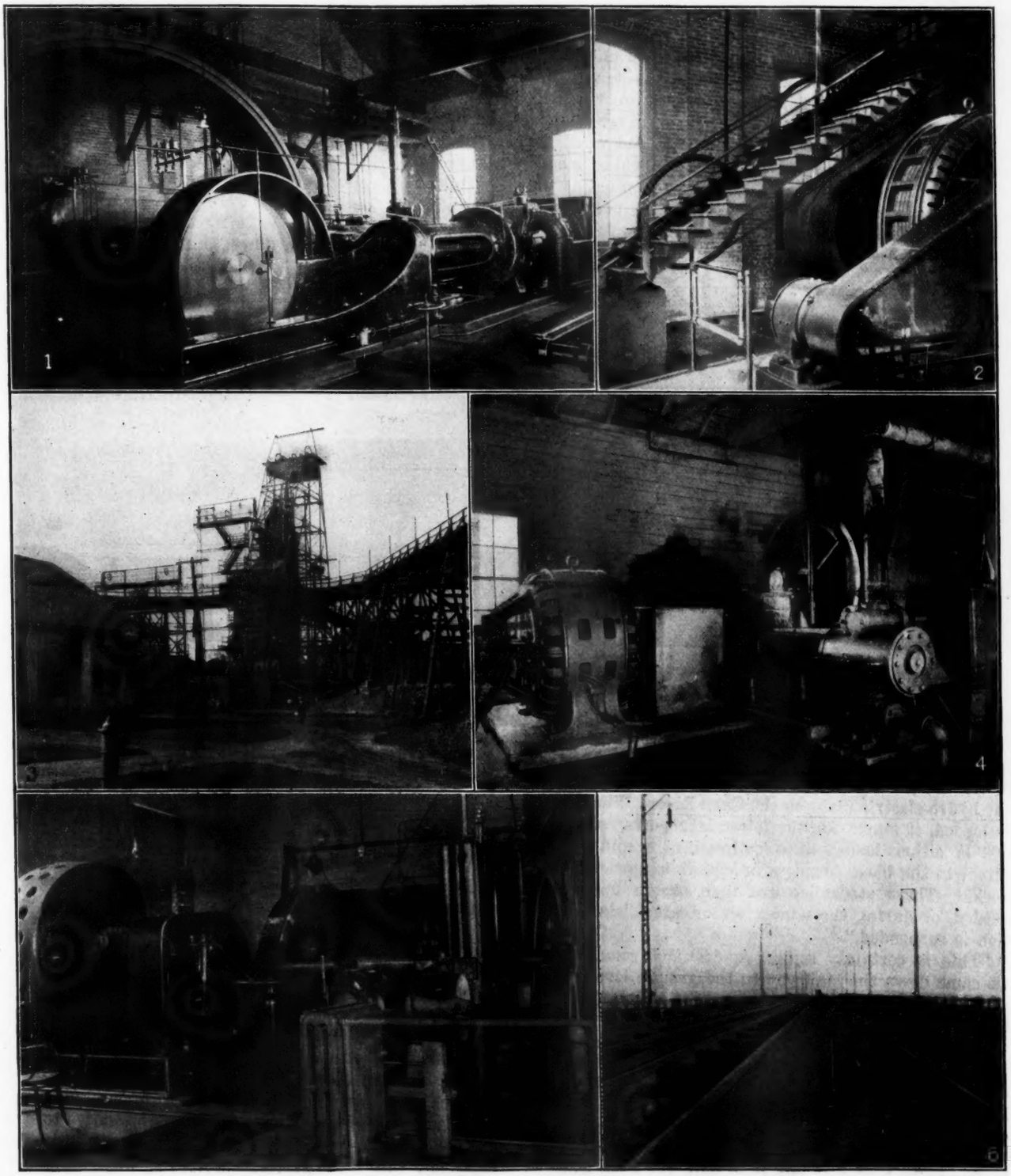
Leaving the Princeton mine, we took a short-cut through the woods to the Gwinn, where we found two motor-driven hoists—one for men, the other for the skip. The man hoist was of the second-motion type; that is, the motor revolved the drum through a geared drive. The 400-hp. motor of the skip hoist operated at 2100 volts and might be termed a third-motion hoist, because the motor drove a jackshaft and that in turn drove the hoisting drum, herringbone gears being used. Fig. 5 shows the outfit. The intermediate gearing was used because of the high speed of the motor.

"That headframe is a pretty piece of work," remarked Hunter, as he saw me squinting through the camera at it (Fig. 3). "The ore can not only be loaded into railroad cars for shipment, but it can be run out on the trestles and dumped in the yard for storage, to be shipped whenever the demand arises. A good idea of the method of supporting the skip ropes is had. The idler-sheave wheels are free to move endwise on a shaft as the cable is wound or unwound on the hoisting drum, so that the cables can assume a straight line from the hoist drum to the large sheave wheel at the top of the headframe. That is the common practice."

On our way back to Ishpeming we passed many cars loaded with iron ore being drawn to the loading piers on the lake front.

"Probably the best loading pier, and I understand the only steel-concrete ore pier in this section, is at Marquette," said Hunter. "It belongs to the Cleveland-Cliffs Iron Co., which also operates its own ore railroad."

I suggested that we take a run down and see it, and we did. Unfortunately no ore steamers were at the pier (Fig. 7) but several were expected. We were told that the pier was 1200 ft. long, 75 ft. high and 54 ft. wide and had 200 pockets, each holding five 50-ton carloads of ore. It carried four tracks (Fig. 6) and could accommodate 200 ore cars, each 24 ft. long. It has a storage capacity of 50,000 gross tons. The fastest loading record at this pier is 11,000 tons in five hours.



FIGS. 1 TO 6. SOME OF THE INTERESTING VIEWS AT THE IRON MINES

Fig. 1—Motor-driven air compressor. Fig. 2—Motor and rope drive. Fig. 3—Headframe at Gwinn mine. Fig. 4—Motor displaced engine hoist. Fig. 5—Third-motion electric hoist. Fig. 6—Tracks on ore dock at Marquette, Mich.

"That is somewhat different from the first cargoes," said Hunter. "It used to be that sailing vessels carried ore cargoes on the lakes, but they have all disappeared and enormous steam ore vessels have taken their place. The first ore cargo down the lake consisted of five barrels—some different from what is carried now.

"The ore cars are taken from the various mines and hauled to the terminal yards, where the trains are broken up and held until shipping orders are received. The ore selected for shipment in a given cargo is then dumped into the ore pockets on the dock, and when the vessel is in place the ore is loaded into the hold by means of chutes. As a number of pockets are emptied at the same time, it does not take long to load a boat. The loading spouts are lowered by gravity and are hoisted by a motor. Each spout is independent of the others, and one motor operates six spouts. The lowering speed is controlled by a brake, and the hoisting of the chute is done by throwing in a clutch connecting with the motor shaft. The electrical energy is supplied from the hydro-electric plant on the Carp River. When a boat is loaded, it starts for the lower lake ports, where the ore is either loaded onto railroad cars and shipped direct to the blast furnaces or else it is stocked at the docks. These stockpiles are then drawn upon when needed, or during the winter season when lake navigation is suspended."

"This is certainly some ore dock," I remarked, as we came down the stairway to the ground level, "but I suppose there are others as large if not larger than this one."

"Unless I am mistaken, the largest ore-loading dock in the world is at Duluth, Minn. It is a steel-concrete dock belonging to the Duluth, Missabe & Northern Railway Co. It has 384 pockets for the storage of ore, each with a capacity of 350 tons, or seven carloads. The working capacity of the dock is 134,400 tons, and six boats can be loaded at one time with the dock working at full capacity. It is figured that a cargo of 9500 tons can be loaded in 30 minutes, but I do not know that it has ever been done. It cost about $2,500,000 to construct."

"That item alone seems to be a mighty high figure just for handling ore for shipment. They must get a good price for mining the ore."

"It is a paying investment in the end," answered Hunter. "Quick service in handling ore is desirable, and ore-carrying boats do not throw away any more time at the loading docks than they have to. The cheaper the ore can be handled the more profits. Back in 1856 the price of iron ore was around $8. When the Mesabi Range began shipping ore in 1892, it had its influence on prices because the ore is high grade and is easily mined. Iron-ore prices fluctuate from around $5.70 per ton for bessemer to about $5 for the nonbessemer grade. The Old Range ores are about 25c. per ton higher."

While this conversation was taking place, we had been waiting for a car and were soon on the journey back to Ishpeming after an interesting day. We had spent a week at the iron mines, and Hunter suggested that we proceed to Houghton, Mich., to take in some of the copper mines.

"You will find," said he, "that the machinery is much the same at the iron mines, and although we might go to dozens of them, they would be so nearly alike that there would not be much of anything new to see except in minor details."

As this suggestion was agreeable and convenient to both, we decided to take the first train for the copper county, which we did.

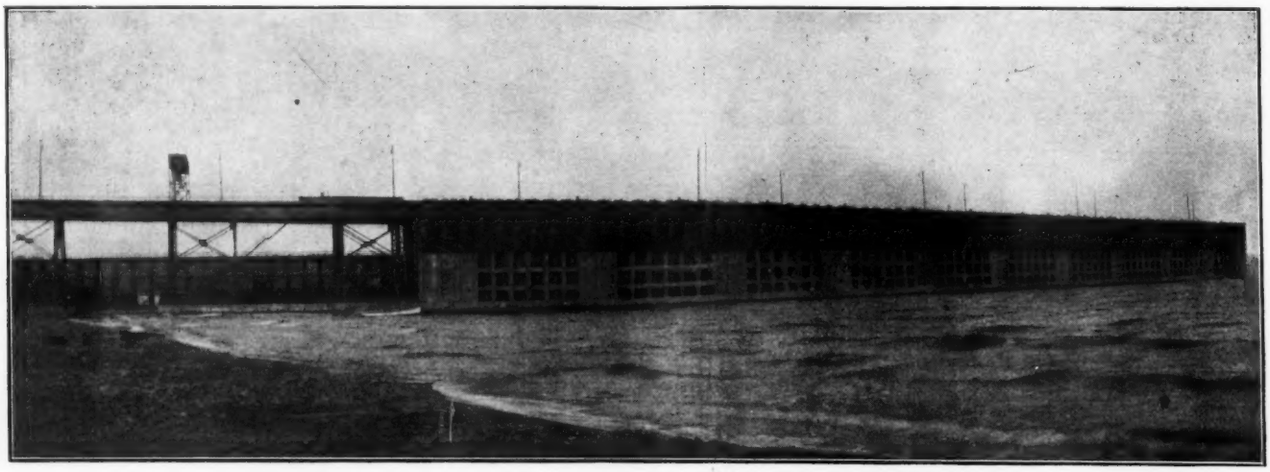


FIG. 7. ORE DOCK AT MARQUETTE; CAPACITY, 50,000 GROSS TONS

Engineering Education

There has been a vast expenditure on technical schools, ranging from the technical school of the small borough to institutions of university rank, but with all these schools and colleges, the difference in the problem of educating engineers and engineering workmen has not been solved. Many still fail to understand that the manual training which enabled an apprentice to become a master craftsman does not suffice to turn a schoolboy into an engineer. Moreover, differentiation is needed in training. Designers and scientific advisers require a knowledge and experience which managers and business organizers and forego, and this lack of differentiation seems to be one cause of the inefficiency of our technical education.—*From Presidential Address, Institution of Mechanical Engineers, by Michael Longridge.*

What the Intercooler Can Do

By FRANK RICHARDS

The function of the intercooler in connection with air compressors is set forth in a more or less formal manner, avoiding abstruse theory and formulas as much as possible. Consideration is also given to the amount of moisture in, and its extraction from, the air.

IT OCCURS to me that there are others who are not altogether sure on the points suggested in the following letter of inquiry from a friend, and that my reply to him may prove of interest to readers of *Power*.

I am in a kind of a mixup about intercoolers on two-stage air compressors, what they are for—although in a general way I suppose I know that—what they will do and what they will not do in the reduction of intermediate air temperatures, also in the reduction of the volume of air entering the high-pressure cylinder and the saving of power effected; but more especially I want to know about the extraction of the moisture and the delivery of the air in a more or less dry condition, so as to avoid all trouble at the drills or elsewhere from freezing up, etc. If you will kindly do what you can toward informing me on these points you will be rendering me a valuable service.

Avoiding theories and formulas as much as possible, consider a compressor having two air cylinders, 30 and 18 in. diameter respectively, with a 27-in. stroke, running at 90 r.p.m. and delivering air at 100 lb. gage. Consider the compressor located at an altitude of 5000 ft. above sea level, then the normal atmospheric pressure will be 12.14 lb.

The piston speed in feet per minute = length of stroke in feet $\times$ number of strokes per minute; or $2.25 \times 180 = 405$, and the volume of free air in cubic feet taken into the low-pressure cylinder per minute will equal the diameter of the piston in inches, squared, $\times$ 0.7854 $\times$ piston speed in feet per minute $\div$ 144, or in this problem $30^2 \times 0.7854 \times 405 \div 144 = 1988$, as the full theoretical capacity of the cylinder; but certain allowances must be made for clearance, piston leakage and leakage and inertia of the valve, for which deduct 10 per cent., leaving 1789 cu.ft. per min., which is probably better than the average performance of up-to-date compressors. The quantity of air thus passing the discharge valve cannot be increased or diminished by the presence of the intercooler, and any increase must be attained by a general overhauling or tightening up of the machine or an increase in speed.

To ascertain the power saved by two-stage compression with efficient intercooling, first find what the power would be for single-stage compression. Assuming, then, that the entire work is done adiabatically in the low-pressure cylinder, with the free air at 12.14 lb. absolute, with the delivery pressure 100 lb. gage, the ratio of initial and terminal absolute pressures will be $12.14 \div (100 + 12.14) = 0.1082$. With this ratio of pressure the ratio of volume, from the formula, $\frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{0.71}$, will be 0.206, and the ratio of temperatures by the formula, $\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{0.29}$, will be 0.5247, where p_1 = initial absolute pressure, p_2 = terminal absolute pressure, v_1 = initial volume, v_2 = final volume, T_1 = initial absolute temperature and T_2 = terminal absolute temperature.

If the initial temperature of the air is, say, 70 deg. F., the terminal temperature will be $(70 + 460) = 530 \div 0.5247 = 1010$ deg. absolute, or $1010 - 460 = 550$ deg. F., and no matter how efficiently the cylinders and cylinder heads are water-jacketed, the discharge temperature of the air will not be below 500 deg. F., which alone gives sufficient reason for avoiding single-stage compression for such a high delivery pressure.

As to the power required to drive the compressor; the mean effective pressure $= 3.463\ p_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right]$ $= 3.463 \times 12.14 \left[\left(\frac{112.14}{12.14}\right)^{0.29} - 1\right] = 38.09$ lb. per sq.in. gage, and the power required in horsepower = (piston diam. in in.)$^2 \times 0.7854 \times$ m.e.p. $\times$ piston speed in ft. per min. $\div$ 33,000 $= 30^2 \times 0.7854 \times 38.09 \times 405 \div 33{,}000 = 330$ horsepower.

Two-Stage Compressor with Intercooler

Comparing this result with that of a two-stage compressor with a reasonably efficient intercooler and supposing for convenience that the intake temperature is the same (70 deg. F.) for both cylinders, it would only be necessary to have the cooling water at 50 deg. F. to secure this condition for the high-pressure intake, and many builders would be ready to guarantee this. The cylinders being respectively 30 and 18 in., the ratio of volume would be $18^2 \div 30^2 = 0.36$, and as intake temperature is the same in both cylinders, the same ratio will apply inversely to the pressures; the intake pressure of the high-pressure cylinder will be $12.14 \div 0.36 = 33.72$ lb. absolute, or $33.72 - 12.14 = 21.58$ gage.

A condition is encountered here that must not be lost sight of in the computation; that is, on account of the cooling effect of the intercooler, the volume of compressed air delivered by the low-pressure cylinder is considerably larger than the volume of air taken in stroke by stroke by the high-pressure cylinder, and it is upon this basis of a larger volume compressed and delivered that the power consumption of the low-pressure cylinder must be computed.

The intake pressure (p_1) of the low-pressure cylinder being 12.14 lb. absolute and the discharge pressure (p_2) being 33.72 lb. absolute, the mean effective pressure, $= 3.463 \times 12.14 \left[\left(\frac{33.72}{12.14}\right)^{0.29} - 1\right] = 14.5$ lb. per sq.in. gage. Therefore the power required for the low-pressure cylinder is $hp. = 30^2 \times 0.7854 \times 14.5 \times 405 \div 33{,}000 = 125.8$ horsepower.

The intake pressure (p_1) of the high-pressure cylinder being 33.72 lb. absolute and the delivery pressure (p_2) being 112.14 lb. absolute, the m.e.p. $= 3.463 \times 33.72 \left[\left(\frac{112.14}{33.72}\right)^{0.29} - 1\right] = 48.69$ lb. per sq.in. gage, and the power required for the high-pressure cylinder will be $18^2 \times 0.7854 \times 48.69 \times 405 \div 33{,}000 = 152$ hp., and the total horsepower for both cylinders $= 125.8 + 152 = 277.8$, which is 84 per cent. of the power required for single-stage compression.

The foregoing computations would be much more complicated if all particulars and allowances had been included, and the actual possible saving of power, even theoretical, would be somewhat less than shown. In fact, the actual saving of power may be said to seldom exceed 12 per cent., instead of the 16 per cent. which the computations show.

It should not be concluded that the saving by the use of the intercooler is scarcely worth what it costs, especially for temporary installations, which compressed-air plants so often are, because this is by no means the case, for the reduction of ultimate temperatures has an important bearing on the general problem.

In the low-pressure cylinder we found the ratio of initial and terminal absolute pressures to be 0.36. Then the ratio of absolute temperatures would be $\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{0.29} = 0.36^{0.29} = 0.7438$. The absolute intake temperature being 70 + 460 = 530 deg., then the discharge temperature for the low-pressure cylinder will be 530 ÷ 0.7438 = 713 deg. absolute, and 713 — 460 = 253 deg. F. The ratio of absolute pressures for the high-pressure cylinder being 0.30, the ratio of absolute temperatures is 0.7055, and the initial temperature 70 + 460 = 530 deg. absolute, being assumed to be the same as that of the low-pressure cylinder by the action of the intercooler. Then the terminal or delivery temperature of the high-pressure cylinder will be 530 = 0.7055 = 751, and 751 — 460 = 291 deg. F.

These delivery temperatures found (253 and 291 deg. F.) are very different from the 550 deg. F. found by single-stage compression to the same final pressure. The lower temperatures would not be sufficient to burn the lubricating oil used and cake or gum up the air valve, but with the high temperature the case is different, as many costly experiences have demonstrated. The reduction of temperature shown can be obtained by the intercoolers of any of the standard compressor builders.

Reducing the Moisture in the Air

Another function of the intercooler is reducing the moisture in the air. The users of compressed air are annoyed by the presence of water in the air delivered, consequently demand dry air. There is, of course, no such thing as dry air anywhere, and the term "dry air" is only relative. Water is carried by air in two different forms or conditions: First, in the normal condition, mixed intimately with the air in the form of invisible vapor. Water in this form is in the air even when the sky is the clearest and bluest and is therefore also in the air when it is taken into an air compressor. The ability of air to thus carry water and vapor is limited and determined by its pressure and temperature. There is for any body of air, a possible point of saturation, a combination of pressure and temperature at which the air will have all the water vapor it can carry, at which point the humidity of the air is said to be 100 per cent.

At this saturation point if the pressure of the air is increased—that is, if its volume is reduced or if its temperature is reduced, either or both—the air will at once have more water vapor than it can carry, although the actual quantity of vapor present has not been increased in any way, and the excess vapor is immediately condensed or converted into actual water. The air thus, without any change in the actual quantity of water contained in it, at once becomes wet air. The water by this change of air condition is not taken out of the air, but remains distributed through it, consisting at first of minute globules which become more or less visible and cause an appearance of fog, mist or clouds. The water thus separated is heavier than the air and will slowly settle down through it and gather on the bottom of the receiver or other vessel in which it is contained. Also, if the air in this condition is passed through a steam separator or similar device, the water may be collected and drawn off. In any separator employed for this service whether a detail of an intercooler or attached to it, only the water liberated in excess of the saturating quantity can be collected and drawn off.

Vapor-Carrying Capacity of Air

The vapor-carrying capacity of the air may be said to be directly as its volume or inversely as its absolute pressure, if the temperature is not changed; that is, if this volume be reduced one-half by compression, or if its absolute pressure be doubled, its water capacity will be divided by 2. On the other hand, if the temperature of the air be increased without change of volume or pressure, its water-vapor capacity will be about doubled for each 20 deg. F. rise. In the operation of adiabatic air compression—and it is practically adiabatic in each cylinder of a two-stage compressor the same as in a single-stage machine—it will frequently if not generally occur that the change in these two conditions, pressure and temperature, will operate against and to an extent neutralize each other, because in the act of compression, reduction of volume is accompanied by increase of temperature.

Following the course of the air through the compressor under the conditions previously assumed for the purpose of observing the water vapor and what becomes of it, we assume that the humidity of the intake free air is 50 per cent. of saturation, or that the volume will have to be reduced one-half or the absolute pressure doubled before the 100 per cent., or saturation, point is reached. The ratio of the volume of air delivered by the low-pressure cylinder to the intake volume is $0.36^{0.29} = 0.484$; then the volume is thus reduced to a little less than one-half. Therefore its vapor carrying capacity is a little less than the one-half required for complete saturation, and so far as the volume above is concerned, there would have been a slight precipitation of the excess vapor. This, however, is so slight as to be negligible, in view of the rise of temperature which occurs at the same time.

Temperature Affects Vapor Capacity of Air

Remembering how rapidly the vapor capacity of air is increased by increase of temperature, it will be seen that a rise of temperature of only 5 deg. F. above the initial 70 deg. would be sufficient to take up all the slight vapor-carrying deficiency shown by the terminal volume.

As a matter of fact the delivery temperature of the low-pressure cylinder was found to be 254 deg. F., a rise of 184 deg., and since the vapor-carrying capacity of the air is doubled with each 20 deg., it is evident

without going into figures that air from the low-pressure cylinder is exceedingly dry, notwithstanding that it carries all the vapor that it had when first taken into the cylinder.

The air on entering the intercooler at a temperature of about 254 deg. is cooled, as assumed, to 70 deg. F., but the air will not give up water until it is cooled to below the saturation point and then only the excess of water above the saturation capacity, no matter how ingeniously the separator is constructed. The air after leaving the intercooler and entering the high-pressure cylinder must be at the saturation point, or, as before stated, its humidity must be 100 per cent. Since so small a portion at the latter end of the intercooler is all that can possibly have been affected as a water separator it would seem to be more reasonable to have the separator a supplementary device through which the air might be passed after the cooling was entirely completed, just before it entered the high-pressure cylinder of the compressor.

The amount of water in the form of vapor actually carried by the air in the case under consideration is calculated as follows: At the assumed temperature of 70 deg. F. and 50-per cent. saturation, the weight of water for 1000 cu.ft. of atmospheric air is about 0.5 lb. The compressor in this problem handles 1789 cu.ft. of free air per minute, and running continuously would compress 2,576,160 cu.ft. in 24 hours, and the water carried through would thus be 1284 lb., say 154 gal., per day. As far as my information goes, but this is not at all authoritative, it might take the intercooler a week to get only one barrel of water from this quantity of air. This is just a hint of what can and cannot be done by the intercooler in eliminating water carried by air. It suggests how ineffective any intercooler is in guaranteeing the working dryness of the air after final compression.

The air entering the high-pressure cylinder necessarily at 100 per cent. humidity, or carrying all the water vapor it can at the existing temperature and pressure, goes through the same process there as in the low-pressure cylinder; that is, although in the act of compression its volume is reduced, its temperature is correspondingly increased, so that it is discharged from this cylinder also as very dry air, and only after its final and complete compression to the working pressure can the draining of the air be effected.

As the vapor-carrying capacity of the air is greatest when its pressure is low and its temperature is high, so its vapor capacity is least when its pressure is high and its temperature low, when it will readily release a large portion of the water. These latter conditions naturally occur, or may easily be produced, after the final compression is finished, when the air may be so completely drained of its water that little or no trouble from that cause will later be experienced by the user.

If the air is to be transmitted only a short distance, there should be an efficient aftercooler very near the compressor, with a separator of sufficient capacity for the final passage and drainage of the thoroughly cooled air before any of its pressure is lost. If the air is transmitted a considerable distance, say half a mile or more, through pipes of liberal capacity, so that the flow will not be too rapid, the air will be well cooled before it reaches its destination, and as it cools it will precipitate the water, to flow along the bottom of the pipes; and if pockets are provided at the low points of the pipe, the water will collect there and should be regularly drawn off.

Steam Engineer's License Examination—XIV

By H. F. GAUSS

The flyball governor. A simple explanation of its action. Effect of loading the governor, range of action, height of rotation, sensitiveness. Stable, unstable and neutral flyball governors are defined and explained. The next and concluding lesson will take up inertia governors.

THE purpose of a governor on a steam engine is to maintain as nearly as possible a uniform speed of rotation. Inasmuch as all governors depend for their action on a variation in the speed of the engine, it is impossible to construct a governor that will maintain the speed absolutely constant, although the desire is to so construct the governor that as small a variation as possible will occur.

There are many conditions that may arise to cause the speed of an engine to fluctuate. For example, the boiler pressure may drop, the load on the engine may increase or decrease, or an excessive amount of steam may suddenly be needed for other purposes. In general, the rate at which work is done in the cylinder of any double-acting reciprocating engine may be expressed in terms of horsepower by the formula

$$Hp. = \frac{PLAN}{33{,}000}$$

where

P = Mean effective pressure, pounds per square inch;

L = Stroke in feet;

A = Area of piston in square inches;

N = Number of strokes, or twice the r.p.m.

If the speed is to remain constant, the only variable in the right-hand member of the formula is P, the mean effective pressure. This is determined from the area of the indicator diagram, and the main factors influencing the area of the diagram are the initial pressure and the point of cutoff.

The initial pressure is controlled by a throttling governor; the point of cutoff by a governor constructed to vary the point of cutoff, or alter the relative positions of the eccentric center and crankpin center. Thus, should the load on the engine suddenly increase and demand a greater mean effective pressure, the throttling

governor opens up the throttle valve, or the cutoff governor operates to secure a later cutoff, as the case may be. The reverse occurs should the load suddenly decrease. Throttling governors are generally of the flyball type, while cutoff governors are of the flyball and shaft-governor types.

These are the two general types of governor commonly used on steam engines, and their many modifications make them applicable to the various engines on the market. The ordinary flyball governor is familiar to everyone, but questions may arise in regard to its operation and use that require some thought for proper answers. The simple flyball governor, often called a pendulum governor, consists essentially of two levers pivoted at their upper ends to the top of a vertical spindle. The lower ends of these levers carry weights in the form of large cast-iron balls that, owing to their centrifugal force when revolving, cause the levers to move out when the engine speeds up and in when the engine slows down. To these levers about midway of their lengths, two more levers are pivoted, the lower ends of which connect with a sleeve on the vertical shaft. Evidently then, as the balls move out and in, this sleeve is caused to rise and fall, and the controlling mechanism is operated. Fig. 1 shows the apparatus as described.

The simple pendulum governor depends for its action upon the centrifugal force due to its revolving weights. To be satisfactory it must be prompt in action, sensitive to small variation in speed and sufficiently powerful to move the throttle valve or controlling device as the case may be.

Flyball Governor Explained

To understand the action of the flyball governor shown in Fig. 1, it would be well first to analyze the action of the various forces applied to the conical pendulum shown in Fig. 2, where the weight W is attached to arm A and revolves at n revolutions per second around the vertical spindle S. It is found that for each speed of rotation the weight remains at a certain fixed distance from the vertical spindle. Evidently, then, the forces acting to cause the weight to fly out farther and those tending to pull it in toward the spindle exactly balance each other.

Let h equal the height of the pendulum in feet, measured as shown, L the length of the arm A, and r the distance from the center of the weight to the spindle. There are three forces acting on the weight: (1) The pull due to gravity, w pounds, acting vertically downward; (2) centrifugal force, F, acting radially out; (3) the pull in the arm A, the resultant of the other two forces, acting in the direction of the arm.

Upon the basis of revolutions per second the centrifugal force has been found equal to $F = 1.23Wrn^2$, and it can be shown that the force opposing the centrifugal force is $W \times \frac{r}{h}$. With these two forces equal $1.23Wrn^2 = W\frac{r}{h}$, and transposing

$$h = \frac{1}{1.23n^2} ft. \qquad (1)$$

This is a remarkable result, inasmuch as it shows that the height h at which the pendulum revolves is independent of everything except the speed; that is, no matter how heavy the weight W or how long the arm A, the height h is the same in all cases for the same speed. See Fig. 3.

In applying equation (1) it must be understood that the speed n must reach a certain value before the ball will start to rise, it being appreciated that the ball must be slightly deflected from its vertical position before it can rise at all. The speed which must be attained before the ball starts to rise is given by

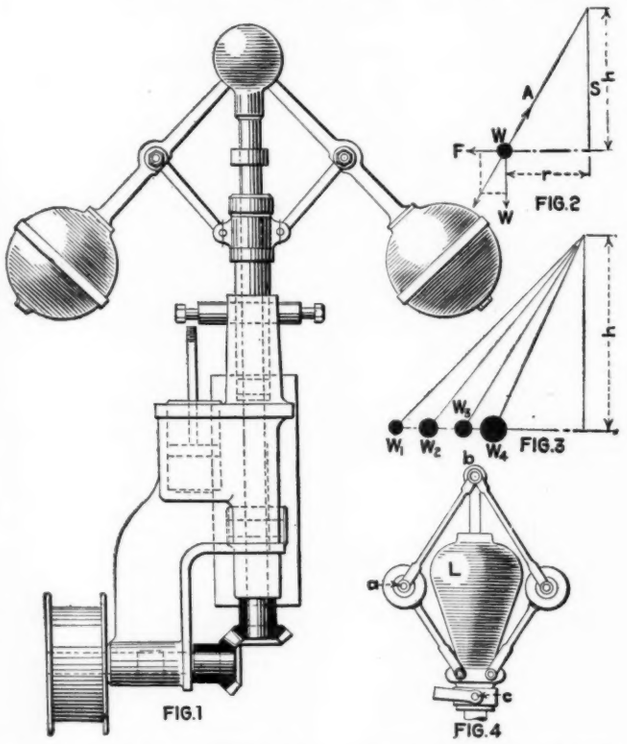
$$n_1 = 0.905\sqrt{\frac{1}{L}} \qquad (2)$$

That is, take a given conical pendulum in which the arm is 1.5 ft. long, the speed at which the weight will start to rise is $n_1 = 0.905\sqrt{\frac{1}{1.5}} = 0.738$ r.p.s. $= 44.28$ r.p.m.

If the height h is expressed in inches and the speed in revolutions per minute, equation (1) must be written

$$H = \frac{35{,}200}{N^2} \qquad (3)$$

Table I was computed from equation (3) and gives the values of N and H through a range of speed from 10 to 200 r.p.m. The change in height is also given, and



FIGS. 1 TO 4. GOVERNORS AND GOVERNOR DIAGRAMS
Fig. 1—The flyball governor. Fig. 2—Action of conical pendulum. Fig. 3—Different weights at same height. Fig. 4—Loaded flyball governor

it is to be noticed that this change for an equal variation in speed becomes smaller as the speed becomes greater, until a change in speed from 120 to 130 r.p.m. produces a change in H of only 0.036 inch.

While equation (3) applies only to the conical pendulum shown in Fig. 2, it may be used to analyze the action of the simple flyball governor. One of the chief drawbacks to this form of flyball governor is at once evident; namely, the speed of rotation is limited to 125 r.p.m., because for higher speeds the height does not change sufficiently for a reasonable variation in speed

to operate the governing mechanism. On the other hand, the resistance to being moved, offered by the governing mechanism, due to friction and inertia, changes the foregoing reasoning to a certain extent. If it is assumed that the friction and inertia simply act as an additional force R tending to hold the weights down, then equating the horizontal forces opposing each other would give $1.23\ Wrn^2 = (W + R)\frac{r}{h}$, which reduces to

$$h = \frac{1 + \frac{R}{W}}{1.23n^2} \qquad (4)$$

Evidently, then, in the case of the actual flyball governor, the height h for a certain speed n (in revolutions per second) is greater than that for the theoretical conical pendulum. This would be an advantage insomuch as it makes a greater speed possible, were it not for the fact that the friction and inertia load is not constant and does not always act down, but merely opposes any motion of the weights. For this reason the weights must be large in order to make the governor sufficiently powerful to overcome the opposing forces, and the larger the weights the greater the inertia of the governor itself and the more sluggish it becomes. The disadvantages of the simple flyball governor may be enumerated as follows: Its speed is limited, the weights must be large and it is sluggish in action.

Equation (4) furnishes a suggestion that has been successfully followed out and has led to the development

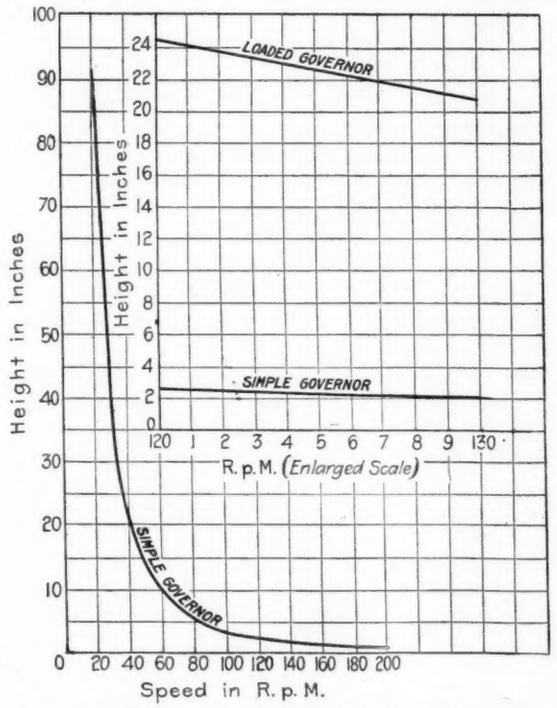


FIG. 5. HEIGHT VS. SPEED OF SIMPLE GOVERNOR

of the loaded flyball governor. A large central weight, L in Fig. 4, is provided, which revolves on the vertical spindle and is carried on the sleeve operating the governing mechanism. For the particular case shown in the figure, where ba is equal to ac, the value of h is given by the equation

$$h_L = \frac{1 + \frac{L + R}{W}}{1.23n^2}, \text{ or } H_L = \left(\frac{35{,}200}{N^2}\right)\left(1 + \frac{L}{W}\right) \qquad (5)$$

In the first formula, where L is large compared with R, the latter may be neglected without appreciable error. Again neglecting friction, comparison with equation (3) will show that the height of the loaded governor is $\left(1 + \frac{L}{W}\right)$ times greater than that of the unloaded governor. Hence, if the ratio $\frac{L}{W}$ is known, it is an easy matter to construct a table giving the values of N and

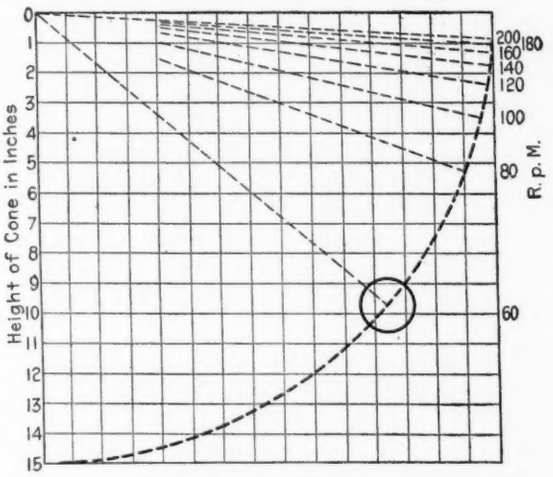


FIG. 6. POSITIONS OF SIMPLE GOVERNOR FOR DIFFERENT SPEEDS

H for various speeds. The new table can be computed from Table I by multiplying the values given there by $\left(1 + \frac{L}{W}\right)$. Table II was computed for a ratio of $\frac{L}{W} = 9$, so that it was necessary only to multiply the values of Table I by 10. By comparing Table II with Table I, it is easy to appreciate the advantage gained by the use of a loaded governor. For instance, at 120 r.p.m. the height of a simple governor is 2.44 in., and at 130 r.p.m. it is 2.08 in., giving a range of motion of 0.36 in.; whereas at the above speeds the heights of the loaded governor are 24.4 and 20.8 in. respectively, giving a range of motion of 3.6 inches.

From equation (5) it can be shown that with $H_L = 2.44$ in., the speed is 380 r.p.m. and with $H_L = 2.08$ in., $N = 411$ r.p.m. That is, for the same height and range of motion, the speed in revolutions per minute are as follows: Simple governor, 120-130; loaded governor, 380-411.

By being able to run the governor at such an increased speed, it becomes possible to greatly reduce the weight of the balls and at the same time secure sufficient centrifugal force to make the governor powerful enough to operate the controlling mechanism. Thus the inertia due to heavy weights is avoided, and the loaded governor can be made less sluggish than the simple one.

Figs. 5, 6 and 7 are instructive and self-explanatory. Fig. 5 shows graphically the relation between the height in inches and the speed in revolutions per minute for the simple flyball governor, and also shows to an enlarged scale the effect on the height produced by loading the governor. Fig. 6 shows graphically the position of the weights corresponding to various speeds for the simple governor, and Fig. 7 the same thing for a loaded governor, in which the ratio of the central load to the weight W is 9.

By the sensitiveness of a governor is meant the ratio of the variation in speed to the mean speed; thus if N_1 equals the maximum permissible speed and N_2 the minimum permissible speed, then the mean speed N is given by $N = (N_1 - N_2) \div 2$ and the sensitiveness is $(N_1 - N_2) \div N$.

From the figures just given for the simple and loaded governor we have

	Simple Gov.	Loaded Gov.
Mean speed	125	395
$N_1 - N_2$	10	31.5
Sensitiveness	8 per cent.	8 per cent.

It is thus seen that the sensitiveness is the same for the unloaded governor as it is for the loaded one; that is, theoretically, loading the governor does not increase its sensitiveness through the same range of motion. However, friction has not been taken into account—one of the most annoying factors entering into the design of governors of every type. The friction existing in the simple flyball governor forms an appreciable part of the total forces acting and hence is more effective in altering the governor action than in the case of the loaded governor, where it forms a much smaller part of the total forces. It is for this reason that the loaded governor is actually much more sensitive than the simple one.

The advantages then, of loading a governor may be summed up as follows: (1) It increases the range of speed through which the governor is applicable; (2) it makes it possible to secure closer regulation, by increasing the vertical movement for a given change in speed; (3) it decreases the sluggishness of the governor by making it possible to employ light weights; (4) it increases the sensitiveness of the governor by furnishing an effective means of offsetting frictional resistances.

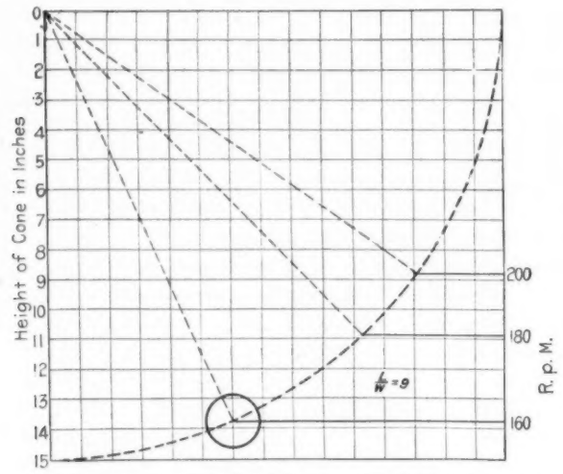


FIG. 7. POSITIONS OF LOADED GOVERNOR

Many types of governor employ springs for loading instead of weights; that is a coiled spring is placed around the spindle and opposes the vertical motion of the sleeve in the same manner as the weight in a loaded governor. A decided advantage is that the spring may be arranged to be adjustable and the speed of the engine varied at will. That changing the load on the governor will change the speed of the engine may be seen from the following: Evidently, when a governor is designed, it must be so proportioned that with the weights in a certain position the throttle is wide open, or the cutoff is as late as possible. This condition obtains when the speed is at the lower limit of its permissible range. When the speed is at the upper limit of its range, the weights occupy a position which closes the throttle or causes the earliest cutoff possible. No matter what the speed of the governor, these results are produced when the weights are in these positions.

From equation (5) it can be shown that by decreasing the load L the speed of the governor necessary to obtain a given height is decreased, and since the speed of the governor is directly proportional to the speed of the engine, it follows that the engine is slowed down. On the other hand, if the weight W is increased then the speed of the engine is also increased.

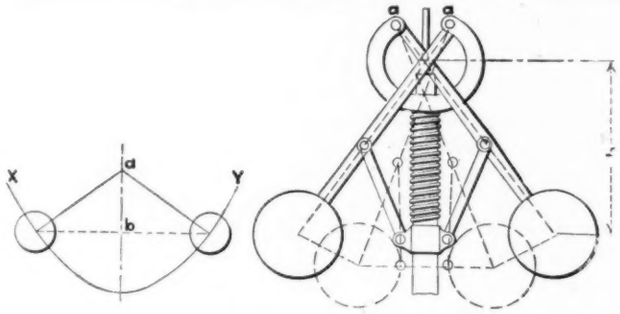


FIG. 8. CROSSED-ARM GOVERNOR

It is evident that by varying the pressure on the spring in a spring-loaded governor, the speed of the engine can be increased or decreased. However, it may be stated in general that a governor should be designed for, and operated at, a certain speed, and though varying the tension in the spring may make it possible to vary the speed, yet the governor will not operate as satisfactorily at these various speeds as at the one for which it was designed. This is due to the fact already pointed out, that the range of motion changes with a change in the range of speed.

If it is desired to make permament changes in the speed of an engine equipped with a flyball governor, it is best to alter the pulley wheels driving the governor, thus maintaining the same governor speed while the speed of the engine is changed.

Take an engine running at 100 r.p.m. with its governor belted up so that it runs at 110 r.p.m. in its mean position. It is desired to so alter the governor pulley, which is 10 in. diameter, that the engine speed will become 125 r.p.m.

Let d_1 = diameter of the pulley on the crankshaft, then at an engine speed of 100 r.p.m.

$3.1416 \times d_1 \times 100 = 3.1416 \times 10 \times 110$; $d_1 = 11$ in.

Let d_2 = the diameter of the governor pulley at an engine speed of 125 r.p.m.

$3.1416 \times d_2 \times 110 = 3.1416 \times 11 \times 125$; $d_2 = 12.5$ in.

The reasoning is self-evident. There are three classes of flyball governors: (1) Stable, (2) unstable, (3) neutral.

1. A governor is said to be stable when it occupies a definite position at a definite speed.

2. A governor is said to be unstable when there is a definite speed corresponding to each position of the balls, but a slight increase or decrease in this speed will destroy the equilibrium and cause the balls to fly to their extreme outer or inner positions.

3. A governor is said to be neutral when at a certain speed it assumes indifferently any position throughout

its range of motion, flying to its extreme outer position at a slight increase in speed and to its extreme inner position at a slight decrease in speed.

The steam engineer is particularly interested in the stable governor, although an approach to the neutral governor is an advantage in that it increases the sensitiveness.

The three classes may be distinguished by the relation which the centrifugal force acting on the weights bears to the radius r, or the distance from the weights to the vertical spindle. It can be shown that (1) if as the governor weights move out, the centrifugal force increases at a more rapid rate than the radius r increases, the governor will be stable; (2) if the centrifugal force increases at the same rate at which the radius r increases, governor will be unstable; (3) if the centrifugal force increases at the same rate at which the radius r increases, the governor is neutral. If the weights can be constrained to move in the path of a parabola whose axis coincides with the vertical spindle, the height h will be constant for all positions of the weight and the centrifugal force will vary directly with the radius, thus fulfilling the condition of a neutral governor.

TABLE I. HEIGHT OF SIMPLE GOVERNOR

N R.P.M.	H Inches	Decrease in H Inches
0	.....	.....
10	352.0	.....
20	88.0	264.0
30	39.1	48.9
40	22.0	17.1
50	14.1	7.9
60	9.78	4.32
70	7.18	2.60
80	5.50	1.68
90	4.34	1.16
100	3.52	0.82
110	2.91	0.61
120	2.44	0.47
130	2.08	0.36
140	1.79	0.29
150	1.56	0.23
160	1.37	0.19
170	1.22	0.150
180	1.086	0.134
190	0.975	0.111
200	0.880	0.095

TABLE II. HEIGHT OF LOADED GOVERNOR

N R.P.M.	H Inches	Decrease in H Inches
0	.....	.....
10	3520	.....
20	880	2640
30	391	489
40	220	171
50	141	79.0
60	97.8	43.2
70	71.8	26.0
80	55.0	16.8
90	43.4	11.6
100	35.2	8.2
110	29.1	6.1
120	24.4	4.7
130	20.8	3.6
140	17.9	2.9
150	15.6	2.3
160	13.7	1.9
170	12.2	1.50
180	10.86	1.34
190	9.75	1.11
200	8.80	0.95

A governor that can be made to closely conform to this condition is the crossed-arm governor, a diagram of which is shown in Fig. 8. The height h is of course the vertical distance from the point of intersection o of the arms and the center of the weights. Points of suspension aa can be found such that for a limited range, the weights will move in approximately the path of a parabola and the governor will be theoretically neutral. If the points of suspension aa are taken nearer the vertical axis, the condition of stability is obtained, and if the points of suspension are taken farther from the vertical, the governor becomes unstable. The ordinary simple and loaded pendulum governors having the arms pivoted at the center line of the vertical spindle are of course stable governors, and the crossed-arm governor is only resorted to in an attempt to increase the sensitiveness by approaching a neutral condition.

The piston rods on locomotives of late models for the Lehigh Valley Ry. are held in the piston head by a single nut provided with a nut lock made from a disk $\frac{5}{16}$ in. thick in the body and $\frac{1}{8}$ in. thick at the circumference. After the nut has been drawn up tight, this disk is cut and bent over on to the faces of the nut. These nut locks are made of dead-soft steel and are used only once.—*Railway Mechanical Engineer.*

Sterling Return Trap

A return trap known as the "Sterling" is now being made by the Templeton Manufacturing Co., Parkway and Sterling St., Cambridge, Mass. It is shown in Fig. 1. The only inside moving part is a float that, when the trap is filled to the point of discharge, moves up into a chamber shown at the top right-hand end of the trap body. One end of the float arm is secured to a shaft that extends through a stuffing-box on one head. An arm on the shaft (Fig. 2) coming in contact with the head prevents the float from striking the trap body. The stuffing-box is in reality not required, as there is a collar on the float shaft that fits against a ground seat, thus making a practically tight joint. The stuffing-box is supplied as a precaution against possible leakage. An arm and weight on the float shaft counterbalance the float.

The trap is provided with two valves, one for admitting steam, the other for venting the trap after it has discharged. Both valves are placed on the top of the

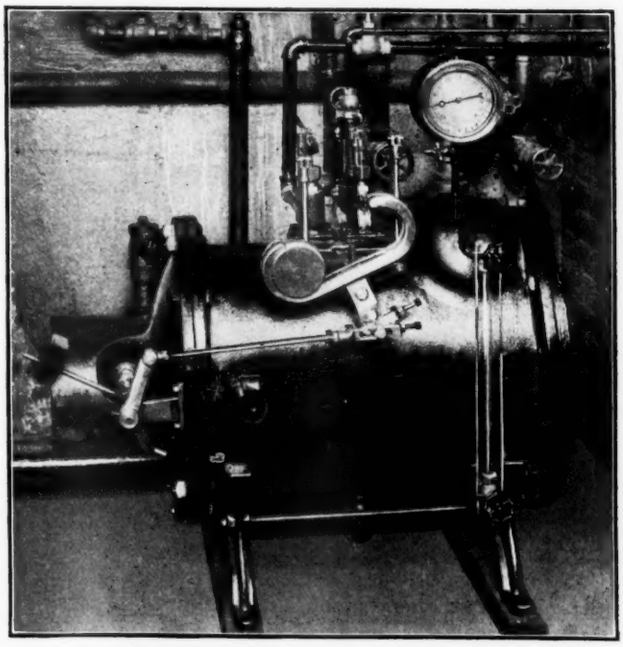


FIG. 1. SIDE VIEW OF STERLING RETURN TRAP SHOWING ROLLING WEIGHT

trap and are of the needle type, seating on renewable seats. The valves are arranged so that the pressure comes on top.

Both valves are operated by a rocker-arm and a weight that alternately rolls from end to end. This movement is transmitted to the valves through links, Fig. 2, that connect with a rocker-arm that is fitted with adjustable screws for regulating the movement of the valves so that they will not open or close until the rocker-arm and weight have passed the center of travel when tilting in either direction.

In order that the rocker-arm will not begin to make its travels from one position to the other too soon, an adjustment has been provided in the link rod connecting the rocker-arm with the float-rod lever. This adjustment permits of controlling the height of water in the trap when it begins and ceases to discharge.

The operation is as follows: When the trap is empty, the rocker-arm and weight are in the position shown in Fig. 1, the float being at its lowest position; the steam valve is closed and the air valve is open. As the water enters the trap through a bottom connection, the float

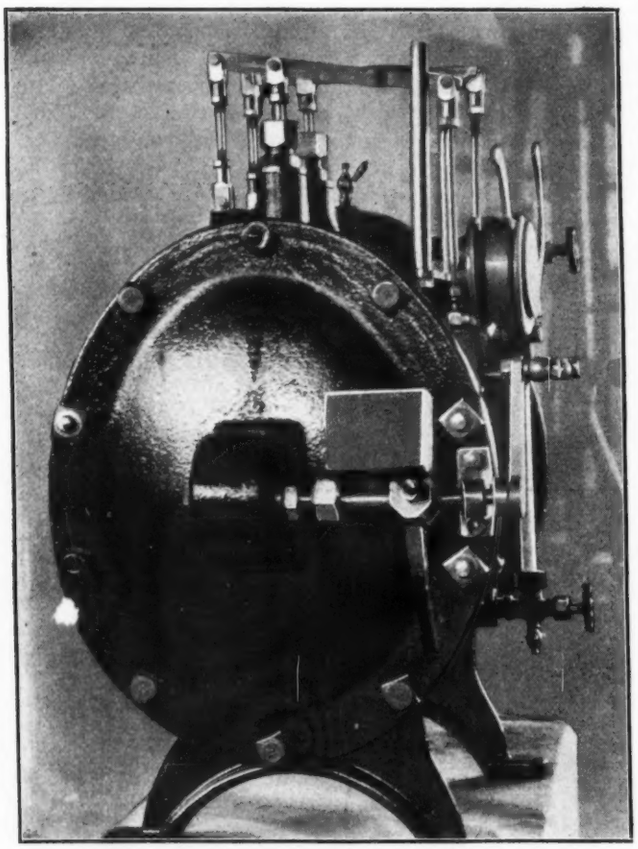


FIG. 2. END VIEW OF STERLING RETURN TRAP, SHOWING VALVE GEAR

rises until the adjusting screw in the link arm strikes a pin that is secured to the rocker-arm. Any further lifting of the float moves the rocker-arm to a horizontal level, and when the movement is a little more, the weight rolls in its track from one end of the rocker-arm to the other with a quick movement, thus throwing the rocker

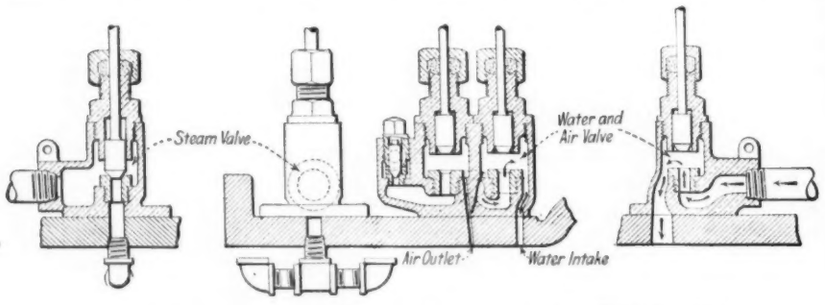


FIG. 3. SHOWING SOME DETAILS OF THE STEAM, AIR AND WATER VALVES

to its opposite extreme travel. This sudden movement of the rocker opens the steam valve, and the steam pressure forces the water into the boiler.

As the water is discharged, the float drops to a lower position until the rocker-arm has assumed a horizontal position, and a further lowering of the float tilts the arm still farther, when the weight rolls to its original position, which movement opens the air valve and closes the steam valve. The trap then begins filling, and the cycle is repeated.

To prevent water-hammer when steam is admitted to the trap, the inlet pipe is fitted with a tee-connection to which a short nipple is screwed in each end, and to each nipple an elbow with the discharge upward (see left, Fig. 3). The water inlet is fitted with a length of pipe perforated with small holes so as to prevent a surging of water during the period when the trap is filling.

A combination valve is provided when the trap is to be used for vaccum or condenser purposes, for the automatic release of air. The construction of the valve is shown at the right of Fig. 3. It is made with two stems controlled by one lever. On the one side is the water-inlet valve and on the other a valve that is in communication with the air. When operating, assuming that the trap is working on a vacuum system, the steam valve is closed and the valve communicating with the vent is open, as the vent valve is practically a floating check valve.

The vacuum will keep the valve closed, and as the water rises in the trap, it begins to compress the air. When the air has assumed sufficient pressure, it will escape. When the trap is ready to discharge, the ball weight rolls over and opens the steam valve and closes the two valves on the one level at the same time. The pressure is on top of the valve, which prevents any liability of its being forced from its seat.

Governing on Three-Cylinder 60,000 Kw. Turbo-Generators

The new 60,000-kw. unit to be installed in the 74th Street Station of the Interborough Rapid Transit Co., New York, where three 30,000-kw. cross-compound Westinghouse turbo-generators have been in successful operation for over two years, will, as previously announced, consist of a high-pressure and two low-pressure turbines, each coupled to a generator. Each of the three turbo-generators making up the unit is to have a governor so arranged that if for any reason the circuit should open on the high-pressure turbo-generator, steam will be shut off from that particular one and the two low-pressure turbo-generators will operate under governor control with high-pressure steam. Likewise, should anything happen to the high-pressure and one of the low-pressure turbo-generators or to the two low-pressure turbo-generators, the remaining one will operate and carry the the load. The turbines, which will operate at 220 lb. abs. steam pressure, 120 deg. superheat, 29-in. vacuum, and the generators, which will have a capacity of 60,000 kw. continuously or 70,000 kw. for two hours, are being furnished by the Westinghouse Electric and Manufacturing Co. of East Pittsburgh, Penn. Their performance will be watched with interest.

Editorials

The Real Efficiency

FROM the earliest days of the steam engine down to comparatively recent years the power-plant engineer was considered a sort of jack-of-all-trades who should be pleased to be allowed the privilege of throwing coal in the furnace, oiling the engine, opening and closing the throttle valve, blowing the whistle, making himself generally useful, and working long hours. But a change has come about, and in most of the large power plants the engineer is now recognized, not as a bill of expense, but as an important element in the efficient operation of the industry—a unit to be considered and encouraged.

However, there are many managers and superintendents of industries that still have this feature, about the efficient operation of a plant as a whole, to learn. Some of them seem to have been inoculated with a "How much coal will it save?" germ. Because it makes no difference what new device the engineer may wish to install in the power plant, the question that he must always answer is, "How much coal will it save?"

This is illustrated by an instance where a synchronous motor had been installed in a plant for doing mechanical work and also power-factor correction, but no instrument had been supplied to indicate when the power factor at the switchboard was correct. For a considerable period the engineer worried along by comparing the volt and ammeter readings with the wattmeter indication. However, one day the man in the engine room sent in a requisition for a power-factor meter. Back came the off-repeated question, "How much coal will the installation of this device save?"

The question in this case indicates about how much this manager knows concerning the efficient operation of a power plant. If the power factor is of such importance that it warrants installing a synchronous motor to correct it, then it also warrants the installation of the necessary instruments to show when results are being obtained. If it were only a case of saving coal, one ton per year at the present prices would pay a reasonable dividend on the price of the instrument. However, coal saving is about the last consideration in improving the power factor, the more important being the increased capacity of the generating and distributing equipment and better voltage regulation. The latter in most cases is the most important because it increases the production of the industry, and often, improved voltage regulation improves the quality of the product. On the other hand, by the installation of the instrument the engineer would be able to see at a glance what the conditions were and to make the necessary adjustments. The time that he would spend making calculations could be turned to other details of the plant, with profit to the industry. Again, there is the psychological effect upon the engineer himself—the good feeling that it would tend to create between him and the management and the incentive to do better work, knowing that his efforts were appreciated.

The saving of coal is evidently not always the only consideration when a new device is to be installed in the power plant, and in many case it is only secondary. The sooner the management begins to realize this fact and to consider the operation of the power plant as it affects the economy of the enterprise as a whole, the sooner will we arrive at a real efficiency.

A Desire To Serve

A CORRESPONDENT in this issue seeks information as to how he may best place his services at the call of the Government. He is not only willing, but anxious, to do his part and wants to serve in the capacity for which by training he is best fitted; but thus far he has been unable to find anyone in authority who could direct him to the proper channels.

The case of Mr. Lewis is typical, and because there are hundreds of other engineers in the same dilemma, we take this opportunity of printing his letter with these comments.

An immense amount of work has been done toward classifying the man-power of the nation. New York State has just completed a census of its citizens and their qualifications. Many of the universities have classified their students and alumni, the national engineering societies have likewise taken account of their membership as to professional experience, as have also many other organizations. In consequence, there has been considerable overlapping and apparently too much well-meant but misdirected effort, and an attempt is now being made to correlate much of this information into a form that will be readily usable. Meanwhile the engineering societies and colleges have been privileged to supply the Government with a large number of men especially qualified for particular work. All of this has been in addition to the contributions of the engineering societies and colleges to the Officers Reserve Corps, which have been, of course, of a strictly military character.

In the first few weeks of the war the authorities at Washington were confronted with momentous problems that required solution before any of the details could be worked out. Moreover, appropriations had to be made before men could be employed. Many of these problems are now being worked out, and with the military plans well under way, attention is being directed toward utilizing the man-power to the best advantage. One evi-

dence of this has been the establishment of the school for training marine engineers and navigators for the merchant fleet, as was recently announced in *Power*. Here is just one way in which some of our readers may serve. Perhaps other opportunities will be offered in connection with the numerous cantonments, each requiring heating and lighting service, water-works and many other engineering features.

Experience thus far has shown that when the Government wants men, it usually requires them on short notice, so it behooves those wishing to serve to hold themselves in readiness.

Carelessness Causes Accidents

ON ANOTHER page of this issue is a letter containing an account of several accidents that occurred in power plants because of carelessness on the part of some workman.

Careless workmen are dangerous in almost every pursuit, and carelessness means injury to someone sooner or later. With the publicity that has been given to the safety-first movement, one would suppose that every workman would have the slogan as firmly fixed in his mind as the commuter does that his evening train leaves at five-fifteen, but such is not the case.

It is just as careless for anyone to fail to report unsafe conditions as it is for him to do his work in a manner that is dangerous not only to his fellow workmen but to himself as well. It is just as careless to allow a piece of loose material to lie around where a man may fall over it as it would be to place the obstruction yourself; and here the adage, an ounce of prevention is worth a pound of cure, is true. If every workman would realize that the prevention of accidents and injuries by all possible means is a personal duty that each one owes to his fellow workmen, there would be fewer accidents.

How many men will take the trouble to turn a board with a protruding nail, to remove a box from a stairway, or a tool that is overhanging the edge of a platform? Surely simple things to do, yet by many it is regarded as too much trouble to bother with these seemingly trivial matters. This same class of men will go into the power plant and be just as careless of others in carrying out their everyday duties. If they were accused of being careless, they would probably protest indignantly.

Probably most accidents are caused by workmen who are habitually careless. It is not uncommon to see a plank stretched from one battery of boilers to another with an insecure landing at either end. Men are supposed to pass on such insecure walkways in the course of their duties. Some firemen leave their fire tools scattered carelessly about the boiler-room floor. Others leave them propped against the wall, ready to fall at the least touch. A little carefulness would prevent most of the accidents that are caused by others.

One common fault is that of taking things for granted and not taking the trouble to investigate. How many times has a fire been built in the furnace of an empty boiler, a partly filled gage-glass with closed stop-cock being relied upon as an indication of the water level? How many chief engineers know the exact condition of their boilers? Most of them rely on the report of firemen who may or may not be competent to judge.

The present industrial-accident record is about thirty-five thousand men killed and two million injured annually. This in spite of the safeguards that have been adopted either as a result of acts of law or because the owners or managers have been awake to the liability of accidents. These figures could be greatly reduced if everyone would coöperate in the work of eliminating carelessness and preventing conditions tending to accidents.

Economy of Smoke Abatement Under Government Control

A SUGGESTION is contained in the letter by the Chief of the Bureau of Smoke Regulation of Pittsburgh appearing on page 127 of this issue, to which we desire particularly to call attention and if possible emphasize. It is that "the question of smoke regulation and its effect on the conservation of fuel should be under Governmental control." Surely, in times like these, when all of the nation's energies are bent in the direction of economies of all kinds, this means of conserving a necessary natural resource should receive its full share of attention. Many innovations proposed interfere more or less with what has come to be considered personal liberty or may entail costs out of proportion to the gain to the individual if not to the public as a whole. But the abatement of smoke has been so thoroughly tried out and in most cases has showed economy of fuel, that pointing out the means and requiring its practice is a decided benefit rather than a hardship.

The instances cited in the letter referred to are typical and by no means extreme, and the percentage of saving from a smaller investment is equally attractive. Smoke abatement laws, to be satisfactory, should be uniform in requirements and application, and this cannot be attained except through the enactment of similar laws by all states or the adoption of a Federal regulation in the interest of uniformity and not as an interference with the sovereign rights of a state.

The violation of a state or Federal law is generally assumed to be more serious than the infraction of a city ordinance and enforcement is therefore less difficult. Coupled with this, a general supervision of all steam plants as to their economical operation and the best use of the heat evolved would go a long way toward solving the present fuel-shortage problem and would be a safeguard for the future.

Despite the urgent need of men for engineer officers aboard merchant ships under the Shipping Board, comparatively few desirable men are applying for training in the schools designated to fit them for such work. Is it because there are few men or because the compensation is too meager to stimulate them?

Correspondence

Smoke Abatement Means Economy

I beg to call attention to certain phases of the subject covered by your editorial, "All-Around Coöperation," in the issue of May 29.

It would seem that there is need of more general information as to the proper relation between justifiable smoke regulation, with the resultant complete combustion and increase of production at lower fuel cost, and the fact that, invariably, the emission of dense smoke from stacks is an indication of waste and improper use of fuel. There is not a single instance where smoke abatement has been properly accomplished that has not resulted in a saving of fuel, a more perfect combustion and a necessarily lower unit cost.

Just before reading your editorial, the writer was discussing with some friends the advisability of addressing the United States Government in regard to the appointment of a commissioner or a board of some kind to compel all users of coal to cease causing needless waste, especially as indicated where there is an emission of dense smoke.

Governmental Regulation Should Be Extended

In regulating the use and the price of coal, the Government can hardly avoid regulating its waste. It is understood that 500,000,000 tons of coal was used in this country during 1916. It is safe to say that smoke abatement could bring about a saving of 10 per cent. of this quantity. Therefore at an average cost of $4 per ton there would be a saving of $200,000,000 per year. If this work should be earnestly undertaken under Governmental supervision, the percentage of saving would be increased from twofold to fourfold.

Very recently I learned of a tin-plate company changing from hand-fired furnaces to powdered-coal burners, reducing the quantity of coal from 600 to 280 lb. of coal per ton of plate—getting a better product and making no smoke. There are other cases here where the saving in fuel from smoke abatement has amounted to from 10 to 35 per cent. Officials of the Crucible Steel Co. in their annual report for 1913 state that their saving amounted to $60,000 on a $130,000 investment, and further that there were other incidental savings besides those of labor and fuel.

This question of smoke regulation, with its effect on the conservation of an important natural resource, should be under governmental control. Its importance is too great to be left within the province of cities, counties or states. At this particular time, with the demand for man-power in the army and navy as well as in production, effectiveness depends to a large extent upon smoke-abatement appliances, because thus will be released able-bodied men for productive labor and war purposes. Let me call attention to one instance in this district: A certain large steel corporation changed from hand-firing on one battery of boilers, to stokers, taking twenty men from coal shoveling and placing them in other parts of the plant on productive labor and at the same time doubling the steaming capacity of the plant.

This letter is written to point out your opportunity to call the Government's attention to the necessity for engaging in the matter of smoke abatement directly and specifically as an aid to the conservation of fuel in the conduct of the present war.

J. W. Henderson, Bureau Chief,
Pittsburgh, Penn. Bureau of Smoke Regulation.

Thoughtlessness in Power Plants

The thoughtless man in the power plant is the type that opens the valve on the wrong boiler and traps a fellow employee inside in a cloud of sizzling steam, who blows down the boilers with the blowoff connection open to a dead boiler with men working inside, who unthinkingly closes the wrong switch or grabs hold of a live high-voltage circuit, or numerous other things that could be mentioned. He is thoughtless because he is so busy thinking about what he did yesterday or what he expects to do tomorrow, or puzzling his brains about problems foreign to his work, that he has no time to keep his mind on what he is doing and as a result jeopardizes the lives of his fellow workers and the equipment under his care.

Never Drape a Live Switchboard

Not long ago several painters were painting the ceiling and walls of a large power house. At this particular time they were working above the switchboard. To keep the board and wiring from being spattered with paint, they had draped a large piece of canvas over the board and busses. About this time a friend dropped in to visit the chief, who had also just come in. He gave one glance at the canvas over the switchboard and then asked the chief what would happen if one of the circuit-breakers should open on a heavy short-circuit. The chief saw the point and started to draw the switchboard operator's attention to the dangerous condition, when the thing happened.

The system was 600-volt direct-current, and the circuit-breakers were mounted at the top of the board. The old canvas, soaked with paint, oil, benzine, etc., was hung on top of the board and draped down over the front, probably not being over two inches from the carbon contacts of the breakers. It seemed only an instant after the breaker opened before the canvas was a mass of flames. The smoke and fumes blinded the men, who were working directly above, so they were unable to do anything to save themselves, and to add to the situation one of them dropped a small iron bar which went end first through the canvas and fell across the busbars. There was a flash and a roar as the circuit-breakers for the machines blew out and shut the whole system down. The men, terror-stricken, jumped to the floor. Two of them were seriously injured, one having

both legs broken, and another an arm broken in two places besides several ribs; the rest escaped with minor injuries. The switchboard operator had allowed the painters to cover up the board according to their own discretion and had paid little or no attention to how they did it, because he was busy laying out a wiring diagram for a friend's garage.

In another instance several electricians were rearranging the lighting system in a large refrigerating plant. At this particular time they were working above a machine that was of the twin-cylinder, single-acting type. The watch engineer was regaling the foreman of the electricians with some of his escapades of the previous evening when the chief came along and ordered him to start this particular machine, it being shut down at the time. He had the oiler start the water over the condenser and see that the valves on the condenser were open, while he went around and opened up the oil cups and got the machine ready, keeping up a running conversation with the foreman all the time. After he had the machine ready, he rocked it back and forth a few times to warm it up while he was waiting for the oiler to come back from the condenser. As soon as the oiler returned, he told him everything was all right and to go up on the deck and open the suction valves as soon as the machine was turning over. The oiler did as he was ordered, and the machine had turned over but a few revolutions when the relief valves operated on both cylinders, which, as stated before, was directly below the electricians. Two of them with a little more presence of mind than the others held their breaths while they caught a rope around a girder and slid to the floor. Of the other two, one was overcome with the fumes and dropped to the deck of the machine and was not brought to for over two hours and was laid up for several weeks; the other jumped to the deck, breaking his leg.

The Chief Makes a Serious Error

The signal circuit of one of the old-style "type A" solenoid-operated, remote-control switches in a large substation became inoperative on account of an open circuit, and the chief operator was ordered to repair it. He removed the disconnecting clips from one side of the switch and proceeded to repair the signal circuit. The high-tension side of the system of the station was operated at 6600 volts, three-phase and 60 cycles. When he had the circuit repaired and the switch operating properly, as indicated by the signal lights, he left it in the open position, as shown by the signal light, and ordered one of his assistants, both of whom were new men at this kind of work, to replace the disconnecting clips while he directed the man as to the proper procedure. To thoroughly impress the new men with the hazard of this operation, he related a number of instances where dire disaster had overtaken operators that had neglected to take proper precautions or had not taken the proper care in the operation.

When everything was ready the clip for the first phase was placed without trouble, as this did not close the circuit, but when the attempt was made to place the clip for the second phase, there was a blinding flash and a roar and the station was shut down. The switch, instead of being open as the chief supposed it to be, was closed.

Unless one takes the trouble to look closely at this type of switch, it is not a simple matter to determine if it is closed or open. There was a standing order to every operator on the system to closely inspect this kind of switch before placing or removing the disconnecting clips, in order to determine the position of the switch. When repairing the signal circuit, the chief had reversed the connections so that the switch showed open when it was closed. Being busy with impressing the new men with the danger incident to the operation, he neglected to inspect the switch to determine if the signal circuit indicated correctly, and the result was that the man who was placing the clips was laid up for several weeks with severe burns, the switch was badly damaged and the station shut down for nearly half an hour.

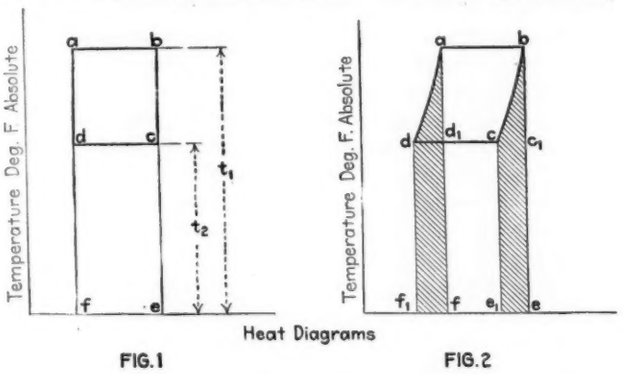
These are but a few striking examples. Anyone can cite such instances, more or less serious, and all of them avoidable if the operator had but kept his mind on what he was doing instead of performing the operation mechanically. The absent-minded man has no business in the modern power plant, and if he is unable to take enough interest in his work to keep his mind on what he is doing, he had better look for a less exacting vocation where the results of his mistakes are not of much consequence.

E. W. Miller.

Minneapolis, Minn.

Steam-Turbine Regenerative Cycle

As stated by Mr. Gauss in the issue of May 15, page 652, the steam-engine regenerative cycle is not new, but has long been applied to certain types of prime movers with excellent operating results. In this respect, however, it must be remembered that the operating cost (cost of fuel, supplies, labor and incidentals) is usually but a small percentage of the total cost of a unit of power delivered and that this operating cost increases with a reduction in the load factor. The higher the load factor the greater is the advantage of increasing the efficiency of the prime mover. For example, we have seen certain notable cases—the 6,000,000-gal. pumping plant at Wildwood, Penn.,[1] and the 1000-hp. quadruple expansion engine, connected to a two-stage air compressor for the Copper Range Consolidated Co.[2] In these cases the load is practically uniform and the use factor



FIGS. 1 AND 2. GRAPHIC HEAT-WORK EQUIVALENT CHARTS

Fig. 1—Carnot heat-work cycles. Fig. 2—Heat-work cycle modified

[1] Trans. A. S. M. E., Vol. 21.
[2] Trans. A. S. M. E., Vol. 28.

is close to unity. The engine, then, can be designed for its most efficient load, and the large load factor will make it profitable to invest more capital in steam jackets, reheaters and a bleeding system for heating the feed water.

The regenerative cycle is based on the principle of thermodynamics, and, although the so-called Carnot cycle (*abcda*, Fig. 1) is one of maximum theoretical efficiency, there are a number of cycles equal to it in economy. For example, Figs. 1 and 2 are heat diagrams, meaning that the area contained in a closed figure represents heat in B.t.u. given to or taken from the body. In Fig. 1 area *abcda* is the heat equivalent of the work done by the engine working between the temperature limits of t_1 and t_2. The heat added or given to the engine is the area *abefa*, and the heat exhausted is the area *dcefd*. The efficiency is the ratio of $\frac{\text{work done}}{\text{heat added}} = \frac{ad}{af} = \frac{t_1 - t_2}{t_1}$. Fig. 2 is the same as Fig. 1 with the exception that the expansion line *bc* and the compression line *da* are curved but are so drawn that the area cbc_1c is equal to the area dad_1d. Evidently then if, in Fig. 2, the left-hand area $daff_1d$ is shifted to the right of the diagram, the new diagram *abefa* will be identical to Fig. 1.

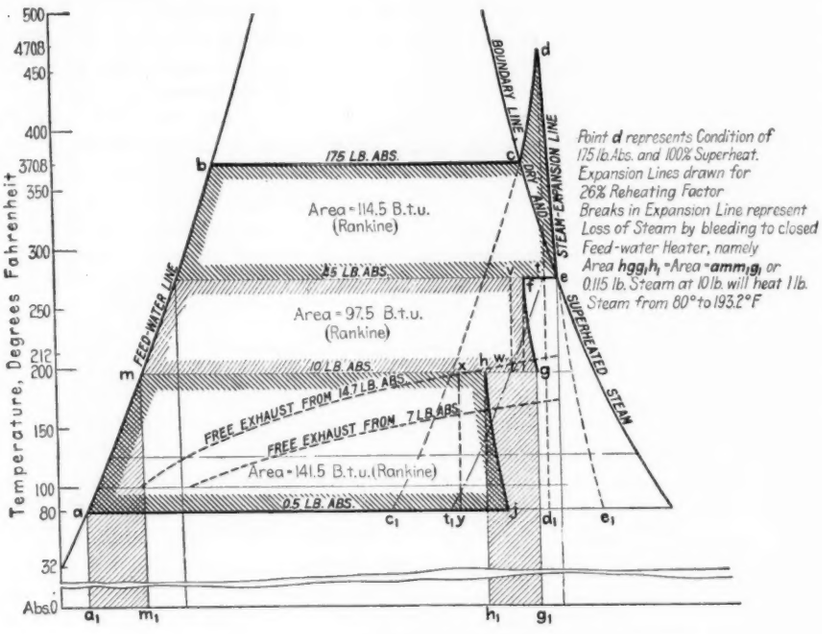


FIG. 3. RANKINE CYCLE HEAT EQUIVALENT OF WORK

The inherent difficulty with the Rankine cycle (*abcdd₁a*, Fig. 3) is that, although the top and bottom lines are isothermals and the right-hand line (the expansion) is approximately an adiabatic, the left-hand line is slanting, showing the heating of the boiler feed to the temperature at which evaporation takes place. Heat is added at gradually increasing temperatures, as shown by the diagram. The regenerative cycle endeavors by bleeding steam during the expansion, by a series of steps, to heat the boiler feed. The bled steam will not accomplish its maximum of work, but its remaining latent heat energy is all available for heating the boiler feed, and when condensed, the condensate flows into the hotwell, thereby utilizing nearly all the heat in the steam instead of some 20 to 30 per cent. The steam regenerative cycle is shown in Fig. 3, the heavy line on the right being the real expansion line (allowing for the reheating factor), the breaks (as *g* and *h*) indicating the amount (0.115 lb.) of steam used to heat the boiler feed from 80 to 193.2 deg. F.

The theoretical efficiency of the new cycle is given by the ratio of the work done to the heat added. The work done by the cycle is given by the area *abcdtvwxya*, which the diagram gives as being equal to 338.5 B.t.u. The heat added is the heat necessary to heat the feed water from a temperature of 274.5 deg. F. to steam at 175 lb. and 100 deg. superheat, which is 1255 — 243.4 = 1011.6 B.t.u., and the efficiency becomes $\frac{338.5}{1011.6}$ = 33.5 per cent. The Rankine efficiency, working between the same temperature limits, has a work area per pound of steam used of 380 B.t.u. (the area $abcdd_1a$), and the heat added is the amount necessary to heat water from 80 deg. to the condition represented by the point *d* in the diagram, or 1207 B.t.u. The Rankine efficiency is $\frac{380}{1207}$ = 31.5 per cent., showing a relative advantage for the regenerative cycle of about 6 per cent. The Carnot efficiency working with no superheat (point *c*) would give $\frac{T_b - T_a}{T_b} = \frac{290.8}{831.5}$ = 35 per cent., but with a temperature represented by the point *d* it becomes $\frac{T_d - T_a}{T_d} = \frac{390.8}{931.5}$ = 42 per cent. The actual turbine expansion line is curved to the right as shown, on account of the paddle wheel and nozzle friction losses which heat the steam and cause additional superheat or a drier quality as the case may be. As compared with the steam-engine regenerative cycle, the turbine cycle has a number of advantages. The use of reheaters, cylinder jackets and oil separators is omitted, and these were the main reasons for the indifferent success of several steam-engine installations of the past. The only difficulty seems to be the continued turbine load, and for central-station work this seems impossible or at least impractical. Since one cannot usually get "something for nothing," it means the employment of a high-class engineer and plant conditions where the load is practically uniform for a considerable part of time. Under these conditions, especially now that fuel is being sold at such high prices, the regenerative cycle is worthy of consideration.

Seattle, Wash. H. J. MACINTIRE.

A new type of agitator for liquids has been developed at the Johns Hopkins University, suitable for producing very minute subdivisions of liquids containing finely divided solids and has been applied to cleaning used lubricating oils. By the use of the agitator, finely divided carbon or other solid matter can be easily and cheaply separated out.

The Political Economical Side of Engineering

I regret that my paper before the joint meeting of the Boston Sections of the American Society of Mechanical Engineers and the American Institute of Electrical Engineers was not reported more *in extenso* in your issue of May 15.

In the time that is rapidly passing by, the doors leading to the political, social and economic questions have been closed before the engineer and the autocratic sign "*streng verboten*" has been placed before his attempt to see what social service the engineering profession is rendering to society. It has been the privilege of financiers, lawyers and accountants to sit in judgment and decide what the community may get for its share from the toil of the engineer and the workman. This emancipation of those who know how to do things and actually do them shall come to pass. The inspiring signs are already in view when the problems of greatest national importance, such as food supply and transportation, are vested with engineers, not with honey-tongued custodians of dead traditions.

The Social Side of the Power Problem

Why should the engineer be tabooed from discussing in the pages of *Power* subjects pertaining to the social side of the problem involved in the generation and use of power?

My paper before the Boston meeting was entitled "Principal Factors for Selection of the Source of Power." In *Power* it bears the title "Principles of Power Plant Management," though in the entire discussion there is no reference to these principles. It is not the British thermal units and kilowatt-hours that a power engineer is dealing with; it is the community that is served by his handling of incarnate energy, and it is therefore purely and simply the problem of an engineer to see that the community gets the benefit out of his work.

The engineering papers published by our allies throw their pages open to the discussion of social service and social relations of the engineering profession, but the pages of *Power* were closed to the following statements:

> The complexity of the present day's industrial relations, the intricacy of the machinery used and the scale on which modern business is carried out call for such readjustments of social relations and of managerial and business methods that would be able to cope with the changed situation.

Ruling Power to Professional Men

> New conditions demand the end of ruling by amateur business men and the transfer of the ruling power to professional men because from this larger national aspect the humane activity shall serve the common cause and not the personal wish.
>
> The highest law of public interest decrees that those who do not manage their business for the interest of the community shall be denied the privilege of running it at all.

I am quoting from my address these precepts that were not considered worthy to be printed in *Power* chiefly to call the attention of its readers to the fact that these very principles which I uttered in April are actually lived up in our governmental activities in connection with the war situation and will be more so as time goes on.

New York, N. Y. Walter N. Polakov.

What Is the Engineer's Next Duty?

"Wake Up America" has been the cry for some weeks, and it is assumed that many are now at least sufficiently awake to look about and inquire, "What next?" The answer is not forthcoming. The situation may be likened to an early morning call to a fire, for example, with no directing hand to point the way to the conflagration. It is safe to assert that there are literally millions of men not only willing but eager to do their patriotic duty if only they are told what to do or where to report for instruction. The perfectly proper question is being asked over and over again in various ways and tones, "What am I to do?"

There is said to be need of engineers of all kinds, but cannot someone in authority take time to specify just the kind of men that can be used, the qualifications necessary, where to apply, the age limit, service, period, etc.? In short, write the specifications? Many good loyal citizens will grow weary of peddling themselves about from place to place in a conscientious effort to find an opportunity to serve their country.

Anyone who has had occasion to look for help for some special work knows that it is useless to simply advertise "men wanted" and let it go at that. He must state the case fully, and the more carefully he outlines the requirements the greater the likelihood of obtaining the best man for the job. I am sure the engineering press would willingly help in this work. J. Lewis.

New York City.

Who Would Be Liable?

I would like to have the opinion of the readers of *Power* as to an engineer or fireman leaving his post of duty to do other work not properly his. I feel that I have no right to leave the engine and boiler while they are in operation, as I am held liable under the state license laws and the boiler insurance company has a right to expect me not to leave my post of duty. My employer says that since he pays my salary, and not the state, he should direct.

Another question is, What should be done when necessary repairs are reported to the owner and no attention is given to the notice? What I wish to know is if the employers ignore the license of the engineer or fireman, does the license board have any jurisdiction? If an accident should happen while the engineer or fireman is away by order of the employer, who would be liable?

Somerset, N. H. G. T. Andrew.

Viscosity Test by the Engler Method

There are various methods of expressing the viscosity of oils, one of the most used being in terms of the Engler scale. Degrees Engler means simply the ratio of the time it takes a given quantity of an oil to flow through a standard orifice as compared to the time it would take the same volume of water to flow through. Oil is usually sold, however, on the basis of its specific gravity (generally measured in degrees Baumé) and its heat value and moisture content. It is usually assumed that the heavier an oil in degrees Baumé, the more viscous is that oil, but this is not always strictly true.—*From a paper by B. S. Nelson, New Orleans, La.*

Inquiries of General Interest

Motorizing Alternating-Current Generators—What would result if two alternating-current generators were operating in parallel and the prime mover of one was shut off?

W. A.

As far as the generators are concerned, no serious harm would be done. The generator that is not driven by its prime mover will operate as a synchronous motor, drawing power from the other unit. If the prime mover is a reciprocating steam engine, gas engine or waterwheel, the unit will operate satisfactorily running idle; the same thing would be true with small steam turbines that are not lagged. However, for large steam turbines that are lagged, it would only be safe to operate them without steam for a few minutes.

Slapping Noise in Cylinder—What causes a slapping or clicking noise at each end of the stroke of an engine?

M. G.

In cases where the noise occurs in steam engines it will usually be found that the length of the counterbore or depth from the end of the cylinder is so great that the piston ring wipes over the edge of the counterbore. While this serves to prevent the corner of the ring from wearing a shoulder in the cylinder, the portion of the ring that projects into the counterbore is subjected to the collapsing pressure of the steam when the engine is at or very near dead-center and the ring is driven against the bottom of the piston grooves with a slapping or clicking noise. In starting some gasoline engines that employ aluminum pistons made considerably smaller in diameter than the bore of the cylinder to permit of greater expansion, a slapping noise occurs until the piston becomes sufficiently heated to expand more nearly to the same diameter as the bore of the cylinder.

Electrolytically Insulated Aluminum Wire—For what class of work is electrolytically insulated aluminum wire suitable? M. A.

This particular kind of wire is in general used for winding magnet coils requiring relatively small wire and where the insulation requirements are not too severe. However, aluminum wire smaller than No. 30 B. & S. is seldom used, as sizes smaller than this are very difficult to draw. This wire has particular advantages in coils where light weight is required and comparatively high temperatures have to be contended with. In large-size conductors where space is limited, there is no advantage in using aluminum wire on magnet coils. At the present time the high price of aluminum has practically eliminated its use for electrical conductors except where absolutely necessary.

Boiler Feed with Top Connection—What are the advantages and disadvantages of top feed connections for horizontal return-tubular boilers? E. L. L.

The advantages of a top feed are, removal of the connection to the shell away from the heat of the fire, and that by extending the feed-pipe connection for some distance through the boiler with the discharge distributed by a number of perforations and away from the shell, the feed water may become heated nearly to the temperature of the boiler water, thus saving stresses due to sudden local cooling of the tubes or shell at times when feed water of low temperature is supplied. The principal disadvantages of the top feed are that the piping within the boiler may become clogged with rust and scale without notice, proper inspection requiring the boiler to be empty, and the internal piping is more difficult to replace than external piping.

Allowable Pressure for Crown Bars—What would be the allowable working pressure for girders of a combustion chamber each made of two rectangular plates ¾ in. thick, 5 in. deep, 24 in. between supports, spaced 8 in. between centers and supporting stay-bolts pitched 8 in.? H. M.

The A. S. M. E. Boiler Code provides that crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following formula:

$$\text{Maximum allowable working pressure} = \frac{C \times d^2 \times T}{(W - P) \times D \times W}$$

where

W = Extreme distance between supports, inches;
P = Pitch of supporting bolts, inches;
D = Distance between girders, center to center, inches;
d = Depth of girder, inches;
T = Thickness of girder, inches;
C = 7000 when the girder is fitted with one supporting bolt, 10,000 with two or three supporting bolts, 11,000 with four or five supporting bolts, 11,500 with six or seven supporting bolts, and 12,000 with eight or more supporting bolts.

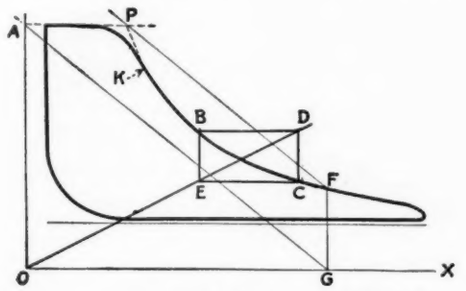
In the example W = 24 in., P = 8 in., D = 8 in., d = 5 in., T = ¾ × 2 or 1.5 in.; two stays per girder, C = 10,000. Substituting in the formula:

$$\text{Maximum working pressure} = \frac{10{,}000 \times 5 \times 5 \times 1.5}{(24 - 8) \times 8 \times 24}$$

$$= 122 \text{ lb. per sq.in.}$$

Locating Point of Cutoff on Diagram—How is the point of cutoff located on an indicator diagram? L. S.

The point of the stroke, where the steam valve is assumed to be completely closed, is indicated by the beginning of hollowness of the expansion line. In the figure it would be at the point *K*, where the direction of the curve reverses. To determine at what point cutoff should occur, assuming initial pressure to be uniformly maintained in order that the expansion line may pass through a point like *F*, it is first necessary to determine the position of the line *OA*



LOCATING CLEARANCE AND CUTOFF

representing the position of the boundary of the clearance space. For this purpose, select any two points, as *B* and *C*, on the expansion curve and draw lines as *BD* and *EC* parallel to the atmospheric line; also the perpendicular lines *BE* and *DC*, forming a rectangle *BDCE*. At a distance below the atmospheric line corresponding to 14.7 lb. on the scale of the diagram, draw the line of absolute zero of pressure, *OX*. Then the diagonal *DE*, if extended, will cut the line of zero pressure at the point *O* of the clearance boundary, which can be drawn as a perpendicular *OA*. Drop a perpendicular line from the selected point *F* intersecting the zero pressure line at *G*, and connect *G* with *A* at the height indicating the given pressure. A line drawn through *F* parallel to *AG* will then intersect the given pressure line *AP* at a point *P* which will be the required point at which cutoff should occur in order that the expansion curve may pass through *F*.

Economical Combination of Water-Power and Steam Plants*

By H. ST. CLAIR PUTNAM

A determination of the respective economic limits in steam and water-power development. It is the author's conclusion that practically all water-power plants should be developed beyond minimum power available and hence in combination with a steam plant. The economic limit depends largely on the value of money, fuel, labor, the increased efficiency of steam turbines and the location of the enterprise.

THE development of large steam and water-power plants and the improvements made in the transmission of power have raised new problems as to the most economical methods of operation and combination of several power plants. It is no longer good engineering to regard a power project as self-contained, to be concerned only with the immediate power market, but it must be considered and studied in connection with other power plants, and its design and development should be planned to meet possible future connections with such plants. This paper describes a relatively simple method of solving the different problems that arise in combining different power plants with different costs and different operating characteristics, and especially the use of a method proposed to determine the feasibility of water-power development and the magnitude to which such development should be carried.

Method of Estimating Power-Plant Costs

The proposed method of solution is based upon careful estimates of cost of construction of such power plants as may be required initially and a second estimate of the same plants extended to greater capacity, preferably to not less than double the size of the initial plant. Careful estimates are then made of the annual-capital costs of each of the operating costs at two or more load factors. The method is equally applicable to water-power plants or to steam plants, and naturally can be extended to transmission lines and substations and also to existing power plants and systems. As illustrating the general method of solution proposed, some estimates of costs that were prepared from a rather special case, where special conditions existed, are given. The purpose of these estimates was to determine the feasibility of a low-head water-power development, represented by the data plotted in Fig. 1, and also the economical capacity for which it should be designed. For the purpose of determining possible economical combinations, the results of water-power development were combined with the results that could be obtained from a well-located steam plant of modern design. The author gives estimate costs for a 100,000- and a 200,000-kw. water-power plant, and for a 90,000- and a 210,000-kw. steam plant. The costs for the steam plant are given for one constructed in accordance with the best modern practice and located immediately at the coal mine, where suitable coal can be obtained at an average price of $1 per ton. The capital costs interest at 3 per cent., operating and total annual costs are also presented for 25 per cent. and 75 per cent. load factors and formulas given for estimating the first cost, capital cost, operating cost and the total annual cost. The formulas are also extended to estimating the cost of transmission lines and substations. After this the accompanying table is given, in which the transmission losses are taken as 6 per cent. and the load factor as 100 per cent. The market for power is assumed to be at the water-power end of the line.

*Abstract from a paper presented at a special meeting of the American Institute of Electrical Engineers, New York, June 28, 1917.

RESULTING FORMULAS—100 PER CENT. LOAD FACTOR, 6 PER CENT. LOSSES ADDED

Construction Costs		Per Kw.
A. Water-Power Plant	$5,134,000+	$70.660
(1) Steam plant	$876,720+	$49.297
(2) Transmission line	149,950+	9.503
(3) Substation at w.-p. end	60,000+	6.000
B. Total for Steam Plant	$1,086,670+	$64,800
Interest (3%) and Depreciation		
C. Water-Power Plant	$172,250+	$3.501
(1) Basis 8% interest, etc	428,950+	7.034
(2) Steam plant	$39,530+	$2.661
(3) Transmission line	4,450+	0.410
(4) Substation	3,300+	0.330
D. Total Steam Plant	$47,280+	$3.401
(1) Basis 9% interest, etc	112,480+	7.289
Operation and Maintenance		
E. Water-Power Plant	$30,270+	$1.5746
(1) Steam plant	$53,970+	$10.6751
(2) Transmission line	7,520+	0.1007
(3) Substation	4,100+	0.0770
F. (1) Total Steam Plant, $1 Coal	$65,590+	$10.8528
(2) Total steam plant, $3 coal	88,910+	26.6368

One of the first costs to be determined in the development of a water power is whether it will pay, and if so, whether it is the cheapest and best method of producing the power required. In the case used as an illustration the water power is compared with a steam plant of modern design, located at the coal mine, thus reducing the cost of fuel to a minimum. The comparison, therefore, is most severe. After the cost formulas are developed, the problem is quickly solved. On the basis that the power is to be delivered to a local distribution system at approximately 13,000 volts and 100 per cent. load factor, the formulas in the table become as follows:

Total annual costs, water power, $202,520 + $5.076 per kw. (C + E).

Total annual costs, steam power, $112,870 + $14.253 per kw. (D + F).

Then the point of equality of costs will be found as follows:

$202,520 + $5.076 per kw. = $112,870 + $14.253 per kw.

$$Kw. = \frac{89,650}{9.177} = 9,769$$

That is, if the power required is in excess of 9769 kw., it is better to develop the water power than to build the steam plant. If the steam plant is already built and additional power is required, then the question arises whether it is better to extend the steam plant or construct the water power. This question is answered as follows:

$202,520 + $5.076 per kw. = $14.253 per kw. (C + E = inc. D + F)

$$Kw. = \frac{202,520}{9.177} = 22,068$$

That is, if the increased power desired is in excess of 22,068 kw., it is better to construct the water-power plant than to extend the steam plant. As stations of large capacity are here considered and the steam station is assumed to be equipped with 30,000- or 35,000-kw. steam turbines, it is evident that it is better to construct the water power than to install an additional unit in the steam station.

The estimates used in this memorandum are based upon the development of a water power with low head but with a large volume of water. The characteristic discharge curve for such a stream, together with the potential power that can be developed and the variations in head with different loads are shown in Fig. 1. It will be noticed that with the exception of two or three days in the period of 15 years the power during low-water periods does not drop below 30,000 kw. It is evident from the foregoing deduction, therefore, that the water power should be developed

under the conditions assumed rather than to construct a steam plant and transmission system or extend the steam station.

It has been found profitable to develop water powers beyond the minimum flow of the stream when a market for the power is available. If there is no market immediately at hand, in many cases new industries grow up and absorb the power after such developments are made. It is important that the best water-power development to make be determined in advance and the manner in which increased demands for power are to be met. There has been a tendency quite general among bankers and investors to regard a water power as limited by the minimum flow and to look with suspicion upon the proposition to include an auxiliary steam plant as the necessary part of a water-power development. As a matter of fact, practically all water powers have auxiliary steam plants in connection with them, but, unfortunately, the auxiliary plants are often uneconomically furnished by the customer. Much better engineering and much greater economy are obtained if the question of auxiliary steam plants for a water power is met boldly and adequate provision is made for it in the beginning.

Maximum Economical Capacity

In the case used as an illustration, it is clear that if the power required exceeds 10,000 kw., the water power should be developed rather than a steam plant constructed, and this development can be carried to 25,000 or 30,000 kw. before the question of an auxiliary steam plant arises. Every water-power development should be designed so that its maximum economical capacity can be conveniently developed without reconstruction, and it is important that this capacity should be determined when the original designs are made.

An inspection of the formulas in the table shows that there are material differences in the distribution of costs, and it is evident that the costs can be combined so as to obtain the point where power is produced at a minimum cost. As it is assumed that the water-power plant will be developed beyond minimum flow, an increase in the installed capacity of the water-power plant will require a corresponding increase in the capacity of the auxiliary steam plant, so the increase in capital costs in both plants must be offset by the saving effected, and the water power can be extended until the net result is zero. When the steam plant is larger than the water power, the water power is used to supplement the steam plant when and as it is available. In this case the capital charges of the steam plant need not be considered, and the increase in the development of the water power must be justified by the saving in the operating cost of the steam plant, and the development of water power should be stopped where the saving resulting from such an extension becomes zero.

Protecting Building Over Genetarors

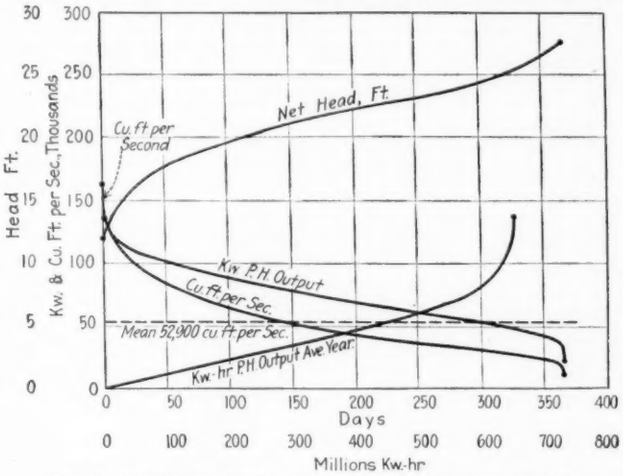
Direct-connected waterwheel generators are now generally used in hydro-electric developments, but when the head is low, these generators become costly on account of the low speed and the large volume of water to be passed through them. The generators must have small capacity relatively to those used in steam practice. Where the power development is large, the result is that the power-house buildings and foundation, as well as the waterwheels and generators, become serious factors in the cost of such a power development. With the case used as an illustration the power station must be from one-quarter to one-half mile in length, according to the size of the generating units used, and this is a serious factor in the cost of development. The suggestion is here made to place a simple protecting building over the operating room and to place the switching gear, transformers, etc., in a substation building on shore, the power house being used simply as a generating room. Instead of building a high and costly structure to support and contain the crane, an external gantry crane is used and the apparatus in the station is reached through a removable transom in the roof. This method of design greatly reduces the cost of power-station construction.

The effect of a reduction of the load factor below the 100 per cent. used in this discussion would be to increase the number of days per year during which the waterwheel must be operated in order to justify its installation. On the other hand, if pondage is available above the dam, the kilowatt capacity that can be installed may be increased.

The reserve generating unit, for obvious reasons, should be placed in the steam plant. An entire spare circuit should be provided in the transmission line as a reserve, and a reserve set of transformers should be provided in the substation. These reserve factors will appear as constants in the formula expressing costs, and hence do not enter into the problem of the determination of the most economical development of the power.

Financial efficiency might be defined as the greatest earning power of a dollar. This may or may not be a controlling factor in a water-power development, although it is believed that as a matter of good policy it should not be. It is conceivable, for instance, that in the long run it might be better in an initial development to earn 10 per cent. on $200,000 than 20 per cent. on $100,000.

It is feasible to use gas instead of coal in the production of power in the auxiliary steam plant. In most cases gas can be burned under boilers with better results than in gas engines, on account of the low cost and high efficiency of the modern steam turbine. It is now possible to obtain from all bituminous coals, whether coking coals or not, byproducts of great value, by the use of either producer-gas or coking plants. In many cases the sale of the byproducts will pay all the costs of the byproducts plant, including that of coal. The gas for use in the steam-power plant will be a surplus product, or an additional profit, which can be



AVERAGE OF 15 YEARS' DURATION FLOW CURVE

added to the profits of the enterprise. Such byproduct plants should receive careful consideration in the design of such a power system as is here described.

It is the author's conclusion that, where a market for the power is available or can be created, practically all water powers should be developed beyond the minimum power available, and hence all water-power plants require steam plants in connection with them.

Water-power plants are most valuable when developed in connection with steam plants, and the development should be carried to the point where the best results can be obtained in combination with such steam plants.

The point of economical development of the water power is increased in capacity as the operating costs of the steam plant are increased, such as are due to the increased cost of fuel and labor.

The point of economical water-power development is decreased as the value of money increases. This is true in general, although there are exceptions in the case of water powers with high heads.

The general tendency of coal and labor and other items entering into the operating cost of a steam plant is upward, and as the world increases in wealth the tendency in the value of money will be downward. These factors should be kept in mind in planning the development of a water power, and provisions made for extension of its capacity.

The increase in the efficiency of steam turbines and the construction of steam plants at the coal mines both operate to make it difficult to profitably develop water powers, especially those with low head, where the first cost is relatively high. The development of all possible water powers should be encouraged, both for the conservation of the fuel supply and the economical advantage resulting from the use of power in our industries. It is therefore important that all rights essential to the development of water-power and transmission projects should be given power companies, to the end that the cost of development should be reduced and many serious difficulties now encountered removed. Any policy under which additional burdens are imposed upon water-power developments, whether by the Government or other authority, is against the true interests of the public and contrary to the best utilization and preservation of our natural resources. On the contrary, if a plan could be devised so that Government funds at low interest rates could be used for such developments, similar to the plan used in the construction of the New York subways, the development of water powers would be greatly facilitated and the financial values created would react to the great advantage of the Government.

Proposed Tests for Lubricants*†

1. SPECIFIC GRAVITY—Specific gravity may be determined by hydrometer, Westphal balance or pyknometer, provided these instruments are verified. The observation shall be taken with the sample at 15.56 deg. C. (60 deg. F.) compared with water of the same temperature.

2. STANDARD TEMPERATURES FOR VISCOSITY—Determinations of viscosity shall be made at the following temperatures: 20 deg. C. (68 deg. F.), 40 deg. C. (104 deg. F.), 55 deg. C. (131 deg. F.), 100 deg. C. (212 deg. F.).

3. CLOUD TEST FOR PETROLEUM OILS EXCEPT STEAM CYLINDER AND BLACK OILS—The cloud test indicates the point at which paraffin wax or other solid substances crystallize out or separate from solution in the oil.

Put the oil to be tested in a glass jar or bottle approximately 1¼ in. inside diameter and 4 to 5 in. high, to a height of about 1¼ in., or sufficient to reach ¼ in. above the mercury bulb of the thermometer. The thermometer used is the so-called cold-test thermometer, which is specially made for this purpose and has a bulb ¼ to ⅜ in. long. Insert the thermometer through a tight-fitting cork so that it is held centrally in the jar, with the lower end of the bulb ½ in. from the bottom of the jar. Then place the cold-test jar in a metal or glass jacket 4 to 5 in. high, having inside diameter ½ in. larger than the outside diameter of the test jar. A disk of felt, cork or wax, ¼ in. in thickness, is placed in the bottom of the jacket. Care should be taken that the test jar is placed in the center of the jacket, so that it does not touch the sides at any point. Then put the whole apparatus into the refrigerating mixture and at every drop in temperature of 2 deg. F. when near the expected cloud test, remove the jar from the jacket and inspect, being careful not to disturb the oil by moving the thermometer or otherwise. When the lower half of the sample becomes opaque through chilling, read the thermometer. This reading shall be taken as the "cloud test" of the oil.

4. POUR TEST—The pour test indicates the temperature at which a sample of oil in cylindrical form of specified diameter and length will just flow under specified conditions.

In making this test the same bottle and quantity of oil are used as for the cloud test, and the pour test may, if desired, be made after the cloud test has been determined, in the great majority of cases the cloud test being the higher. In making the pour test, place the jar containing the oil in a close-fitting metal jacket provided at the bottom with a disk of felt or cork ¼ in. thick. Place this in the freezing mixture. At each drop in temperature of 5 deg. F. remove the bottle from the jacket and tilt it until the oil begins to flow—just sufficiently tilted but no more. In the extreme case the bottle should be tilted to the horizontal. When the oil has become solid around the thermometer and will not flow, the previous 5-deg. point shall be taken as the "pour test" of the oil.

Preferably, the cold is applied so that the pour test will be completed in approximately one-half hour. The materials used in the freezing mixture may be ice, calcium chloride or sodium chloride, or solid carbon dioxide with acetone, depending upon the temperature desired in making the tests. For oils congealing or solidifying above +35 deg. F., pounded ice is used. From +35 to +15 deg. F., a mixture of pounded ice and a small addition of salt, 1:20 by volume, may be taken. For temperatures from +15 to −5 deg. F., also use an ice-and-salt mixture, adding about one-third salt. The salt should be very dry and granulated fine enough to pass through a 20-mesh sieve. From zero to −25 deg. F., a mixture of ice and calcium chloride is used. For temperatures lower than −5 deg. F., however, it will be found convenient to use solid carbon dioxide and acetone, by which any desired temperature down to −70 deg. F. can be obtained, or even lower. This freezing mixture is made as follows:

Take a sufficient amount of dry acetone and put it into a covered metal beaker, copper or nickel; put the beaker into an ice-salt mixture and when the temperature of the acetone reaches +10 deg. F. or below, add by degrees

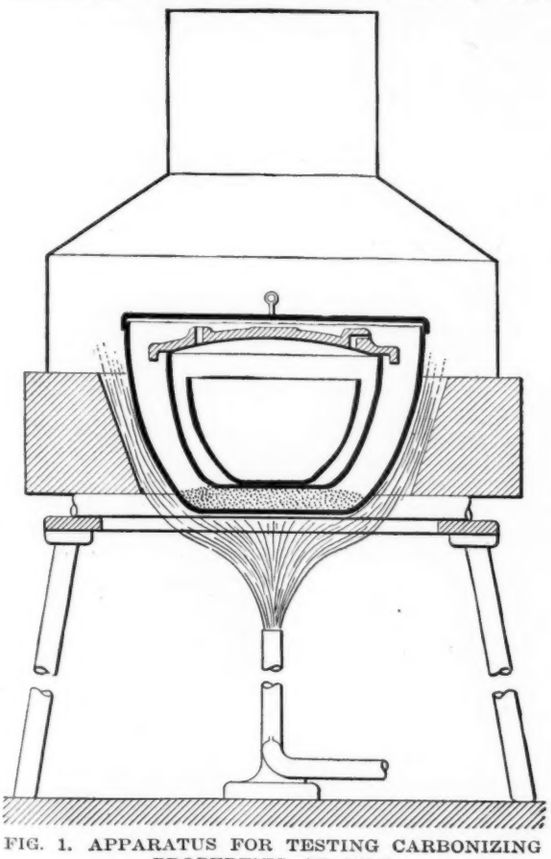


FIG. 1. APPARATUS FOR TESTING CARBONIZING PROPERTIES OF OILS

solid carbon dioxide until the desired temperature is reached. To get the solid carbon dioxide, take an ordinary liquefied carbon-dioxide cylinder and invert it, open the valve carefully and let the gas run out into a chamois-skin bag. By the rapid evaporation the dioxide becomes solid.

5. COLD TEST FOR STEAM CYLINDER AND BLACK OILS—The object of the cold test is to determine the lowest temperature at which oil will flow from one end of a container to the other, in case it should become frozen and the resulting solid oil stirred till it has assumed a sufficiently pasty consistency to flow. The test is conducted by freezing an ounce of the oil solid in an ordinary 4-oz. oil sample bot-

*Presented before the American Society for Testing Materials, Atlantic City, June, 1917.

†Criticisms of these tentative tests are solicited and should be directed, preferably before Jan. 1, 1918, to C. P. Van Gundy, chairman of Committee D-2 on Lubricants, chief chemist, B. & O. R.R., Montclare, Baltimore, Md.

tle, using a freezing mixture if necessary. A thermometer should then be introduced into the frozen mass, and after it has become cold, the bottle containing the congealed oil is removed from the cooling medium. The frozen oil is thoroughly stirred with a thermometer until the mass will run from one end of the bottle to the other, and at this moment the temperature as indicated is recorded. The reading is the cold test of the oil.

If the figures indicating the cold test are inside the bottle and covered by the softened oil, the reading can be obtained by grasping the bottle by the neck with one hand, having in the same hand a piece of waste, which incloses the thermometer. The thermometer is then withdrawn through the waste with the other hand for a sufficient distance to enable the operator to see the end of the mercury column and read the temperature.

6. FREE ACID—Accurately weigh 10 grams of the oil into a flask, add 50 c.c. of 95 per cent. alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly to dissolve the free fatty acids as completely as possible. Titrate while hot with tenth-normal alkali,[1] using phenolphthalein, alkali blue or tumeric as an indicator, agitating thoroughly after each addition of alkali.

Express results either as percentage of oleic acid or as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 gram of fat or oil).

7. CARBON RESIDUE—The apparatus consists of:

a. Porcelain crucible, wide form, glazed throughout, 25- to 26-c.c. capacity, 46 mm. in diameter.

b. Skidmore iron crucible, 45-c.c. (1½-oz.) capacity, 65 mm. in diameter, 37 to 39 mm. high with cover, without delivery tubes and one opening closed.

[1] 1 c.c. of tenth-normal alkali = 0.0282 gram of oleic acid. Alkali, 1 c.c. of which is equivalent to 0.00996 gram of KOH, or 1 c.c. of which is equivalent to 0.5 per cent. of oleic acid, may be used.

c. Wrought-iron crucible with cover, about 180-c.c. capacity, 80 mm. diameter, 58 to 60 mm. high. At the bottom of this crucible a layer of sand is placed about 10 mm. deep, or enough to bring the Skidmore crucible with cover on nearly to the top of the wrought-iron crucible.

d. Triangle pipe, steam-covered, projection on side so as to allow flame to reach the crucible on all sides.

e. Sheet-iron or asbestos hood provided with a chimney about 2 to 2½ in. high, 2⅛ to 2¼ in. diameter, to distribute the heat uniformly during the process; an asbestos block, as shown in Fig. 1.

The test shall be conducted as follows: Ten grams of the oil to be tested are weighed in the porcelain crucible, which is placed in the Skidmore crucible and these two set into the larger iron crucible, being careful to have the Skidmore crucible set in the center of the iron ore, covers being applied to the Skidmore and iron crucibles. Place on a triangle and suitable stand with asbestos block and cover with sheet-iron or asbestos hood to distribute the heat uniformly during the process. Heat from a bunsen or other burner is applied with a high flame surrounding the large crucible, as shown in Fig. 1, until vapors from the oil begin to ignite over the crucible, when the heat is slowed down so that the vapor (flame) will come off at a uniform rate. The flame from the ignited vapors should not extend over 2 in. above the sheet-iron hood. After the vapor ceases to come off, the heat is increased at the start and kept so for five minutes, making the lower part of the large crucible red-hot, after which the apparatus is allowed to cool somewhat before uncovering the crucible. The porcelain crucible is removed, cooled in a desiccator and weighed.

The entire process should require about half an hour to complete when the heat is properly regulated. It will depend somewhat upon the kind of oil tested, as a very thin, rather low-flash-point oil will not take as long a time as a heavy, thick, high-flash-point oil.

Engineering Affairs

The Canadian Association of Stationary Engineers will hold its annual meeting at Toronto, July 24-26.

The American Association of Engineers has started to install a service registry, free to the general public, of civil, electrical, mechanical, paving, sanitary, chemical, appraisal, public-utility, ceramic, irrigation and aviation engineers—a complete inventory of the engineering profession. The list will be classified with reference, to qualifications, experience, residence, etc.

The Universal Craftsmen Council of Engineers will hold its convention at Toledo, Ohio, on Aug. 6 to 11. The outlook is good for an unusually large meeting. At a recent meeting of the transportation committee it was estimated that the Eastern delegation from New York and the vicinity, would require two Pullmans via the West Shore R.R., leaving West Forty-Second St., N. Y. C. at 7:45 p.m. Sunday, Aug. 5.

Massachusetts No. 7, N. A. S. E., held a smoker at Clan MacFarlane Hall, New Bedford, on Saturday, July 14. An entertainment was furnished by Jack Armour, Joe McKenna, Bert Self, Billy Furness, Joe Kimber, John Clinton and Young Veria. Joseph Eccleston, president of the New England States Association, was master of ceremonies. Refreshments were served.

The New York Engineers' Protective Association No. 23, N. A. S. E., held its twenty-fourth annual outing on July 15 at Midland Park, Staten Island. Notwithstanding the inclemency of the weather, the attendance was almost up to standard. The rain ceased in the afternoon and outdoor sports of all kinds were enjoyed. There were prizes for the winners of each event. The outing committee included Edward Miller, Frank M. Paulsen and Maurice O'Donnell.

Jersey City Association, No. 1, N. A. S. E., held a smoker on Saturday, July 7, at its new quarters in Arcanum Hall, corner Jackson and Clinton Aves., Jersey City, N. J. There were speeches by several of the local and visiting members. An entertainment was given by Bert Self, Joe McKenna, Billy Murray, Joseph Scott and Jack Armour. Jack Callahan, the poetic toastmaster, officiated. Refreshments were served aplenty.

Personals

L. M. Johnson, for the last eleven years chief engineer of the Keystone Bank Building, Pittsburgh, Penn., has resigned to accept a position as an erecting engineer in the service department of the Westinghouse Electric and Manufacturing Co.

E. M. Plummer, formerly chief engineer of the Atlantic City (N. J.) Electric Co., is now in charge of the new Windsor station belonging to the American Gas and Electric Co.

Arthur B. Lisle, general manager of the Narragansett Electric Lighting Co., of Providence, R. I., was elected president of the New England Section of the National Electric Light Association at its meeting in Boston on June 29.

Prof Vladimir Karapetoff, of Cornell University, is spending this summer with the Commonwealth Edison Co., of Chicago. He is engaged on some problems in connection with coal supply and purchase under John F. Gilchrist, vice-president of the company.

John F. Glenn, contracting engineer for the past seven years for the Wickes Boiler Co., at Buffalo, N. Y., is now New England sales manager for the Edge Moor Iron Co., and is located at 79 Milk St., Boston, Mass.

H. C. Carroll, formerly chief engineer of the Muncie Electric Light Co., Muncie, Ind., is now with the Indianapolis Light and Heat Co., Indianapolis, Ind.

D. B. Mugan, formerly in charge of the electrical department of the Illinois Central R.R. Co., at New Orleans, La., has been appointed resident manager of the Edison Storage Battery Supply Co., with headquarters at 201 Baronne St., New Orleans.

Fred J. Postel, of Chicago, has been appointed supervising engineer of the newly created Department of Public Works and Buildings of the State of Illinois. Mr. Postel was associated for six years with Charles G. Armstrong, formerly state engineer of Illinois, and has been engaged in general consulting engineering practice in Chicago for the last 12 years.

Business Items

The Lincoln Electric Co., of Cleveland, Ohio, has opened an office at 10 High St., Boston, Mass., under the direction of W. A. Blachford.

The Baffle Wall Renewals Co., owing to increasing business and necessity for larger organization, has become affiliated with the Engineer Co., of New York. J. W. Putnam will give his entire time to the construction department.

McCrossin & Darrah, link-belt engineering experts, represent the Link-Belt Co. at Birmingham, Ala.

Warren Webster & Co. announce the removal of their Atlantic City (N. J.) branch office from 140 South Maryland Ave. to new and enlarged offices at 429 Guarantee Trust Building, with Sidney B. Strouse in charge.

Trade Catalogs

Automatic Temperature Controllers. The Foxboro Co., Foxboro, Mass. Bulletin No. 112. Pp. 20; 8 x 10½ in.; illustrated.

Gas and Gasoline Driven Air Compressors. Chicago Pneumatic Tool Co., Chicago, Ill. Bulletin 34-Y. Pp. 24; 6 x 9 in.; illustrated.

Mechanical Stoker, Type E. Combustion Engineering Corp., 11 Broadway, New York. Bulletin B-2, Second Edition. Pp. 24; 6 x 9 in.; illustrated.

Heavy Duty Direct Current Motors. Reliance Electric and Engineering Co., Cleveland, Ohio. Bulletin No. 2014. Pp. 16; 8 x 10½ in.; illustrated.

The Lincoln Electric Co., of Cleveland, Ohio, has recently issued an extremely valuable booklet on the subject of arc welding as applied to steel foundries, street-car lines, ship and marine work, locomotive shops, automobile and drop-forging plants and general shop work. In this age, when all industries must be put upon the plane of maximum efficiencies and all material must be conserved and work speeded up, the arc-welding equipment is destined to become the source of thousands of economies.

THE COAL MARKET

Boston—Current quotations per gross ton delivered alongside Boston points as compared with a year ago are as follows:

ANTHRACITE

	Circular[1]		Individual[1]	
	July 21, 1917	One Year Ago	July 21, 1917	One Year Ago
Buckwheat	.....	$2.05—3.20	$6.00—6.75	$3.25—3.50
Rice	.....	2.50—2.65	5.20—5.85	2.70—2.95
Boiler	.....	.....	..... *	.....
Barley	.....	2.20—2.35	4.90—5.00	2.35—2.60

*No prices quoted.

BITUMINOUS

Prices per gross ton for Boston delivery are as follows:

	F.o.b. Mines*		Alongside Boston†	
	July 21, 1917	One Year Ago	July 21, 1917	One Year Ago
Clearfields	$3.65 up	$1.10—1.60	$8.75—9.00	$4.25—5.00
Cambrias and Somersets	3.60 up	1.35—1.75	9.00—9.25	4.60—5.40

Pocahontas and New River, f.o.b. Hampton Roads, is $5.15—7.00, as compared with $2.85—2.90 a year ago; on cars Boston price is $9.50—10.

*All-rail rate to Boston is $2.60. †Water coal.

New York—Current quotations per gross ton f.o.b. Tidewater at the lower ports* as compared with a year ago are as follows:

ANTHRACITE

	Circular[1]		Individual[1]	
	July 21, 1917	One Year Ago	July 21, 1917	One Year Ago
Buckwheat	$4.00—4.15	$2.75	$4.50—4.75	$2.55—2.75
Rice	3.40—3.60	2.25	3.50—3.75	2.00—2.25
Barley	2.90—3.10	1.75	2.70—2.90	1.75—2.00

BITUMINOUS

	South Amboy	Port Reading	Mine Price
Clearfield	$6.75—7.00	$6.75—7.00	.....
South Forks	7.00—7.25	.....	.....
Nanty Glo	7.00—7.25	.....	.....
Somerset	6.75—7.00	6.75—7.00	.....
Quemahoning	7.00—7.25	7.00—7.25	.....

*The lower ports are: Elizabethport, Port Johnson, Port Reading, Perth Amboy and South Amboy. The upper ports are: Port Liberty, Hoboken, Weehawken, Edgewater or Cliffside and Guttenberg. St. George is in between and sometimes a special boat rate is made. Some bituminous is shipped from Port Liberty. The freight rate to the upper ports is 5c. higher than to the lower ports.

Philadelphia—Prices per gross ton f.o.b. cars at mines for line shipment and f.o.b. Port Richmond for tide shipment are as follows:

	Line		Tide	
	July 21, 1917	One Year Ago	July 21, 1917	One Year Ago
Buckwheat	$2.90	$1.65	$3.80	$2.55
Rice	2.40	1.00	3.40	....
Boiler	2.20	.90	3.30	1.80
Barley	1.90	.75	2.15	....

Pittsburgh—Price of steam coal per net ton f.o.b. mine, Pittsburgh district:

	July 21, 1917	One Year Ago
Slack	$3.00—3.25	$0.80—0.90
Mine-run	3.00—3.25	1.30—1.40
¾-in.	3.50—3.75	1.40—1.50

Add 40c. per ton for freight charge to Pittsburgh.

Chicago—Current prices per net ton f.o.b. mines are as follows:

	Williamson and Franklin Counties	Saline and Harrisburg	West Virginia Smokeless	Springfield	Clinton and Sullivan Counties
Steam lump	$3.50	$3.50	$3.25	$2.75–3.00	$2.75–3.00
Lump	3.50	3.50	3.50	3.25–3.50	3.25–3.50
Egg	3.50	3.50	3.50	3.25–3.50	3.25–3.50
Nut	3.50	3.50	3.50	3.25–3.50	3.25–3.50
No. 1 nut	3.50	3.50	...	3.25–3.50	3.25–3.50
No. 2 nut	3.50	3.50	...	.....	.....
No. 3 nut	3.50	3.50	...	.....	.....
No. 1 washed	3.50	...	...	.....	.....
No. 2 washed	3.50	...	...	.....	.....
Mine-run	2.75	2.75	3.25	2.75	2.75
Screenings	2.75	2.75	3.25	2.25–2.50	2.25–2.50

Hocking lump, $3.50; splint lump, $3.50.

St. Louis—Prices pet net ton f.o.b. mines a year ago as compared with today are as follows:

	Williamson and Franklin Counties		Mt. Olive and Staunton		Standard	
	July 21, 1917	One Year Ago	July 21, 1917	One Year Ago	July 21, 1917	One Year Ago
6-in. lump	$3.25	$1.45	$2.35	$1.25	$2.50	$1.00
2-in. lump	3.25	1.35	2.25	1.15	2.25	.85
Steam egg	3.25	1.35	2.25	1.15	2.25	.85
Mine-run	2.50	1.15	2.25	1.10	2.15	.85
No. 1 nut	3.25	1.45	2.25	1.25	2.25	.90
2-in. screen	2.50	.90	2.25	.90	1.90	.85
No. 5 washed	2.50	.75	2.25	.70	1.90	.70

Williamson-Franklin rate St. Louis, 72½c.; other rates, 57½c.

Birmingham—Current prices per net ton f.o.b. mines are as follows:

	Mine-Run		Mine-Run
Pratt	$3.50	Carbon Hill	$3.25—3.50
Big Seam	2.75—3.00	Cahaba	3.75—4.00
Black Creek	3.75—4.00		

[1]Individual prices are the company circulars at which coal is sold to regular customers irrespective of market conditions. Circular prices are generally the same at the same periods of the year and are fixed according to a regular schedule.

PROPOSED CONSTRUCTION

Conn., Hartford—The Hartford Electric Light Co., 266 Pearl St., voted to increase its capital stock from $4,500,000 to $6,000,000 and will install a 10,000-kw. turbine in its plant at Dutch Point. F. M. Wilbraham, Supt.

Ill., Brockton—Village plans to install municipal lighting plant and would like to receive from manufacturers catalogs of complete plants or separate apparatus. Preliminary information will be furnished for making estimates. Communication desired by mail only. Address P. V. Deames.

Ill., Champaign—Illinois Central R.R. plans to build a 48 x 60-ft. electric power plant on Walnut St. R. W. Bell, Chicago, Supt.

Ind., Julietta—Marion County Commissioners will soon award the contract for rebuilding the power house at the Marion County Asylum for the Incurable Insane. L. K. Fesler, County Aud.

Iowa, Collins—C. E. Lookingham has been granted a franchise to install and operate an electric-light plant.

Iowa, Ottumwa—The Ottumwa Railway and Light Co. plans to build a high-tension transmission line from Ottumwa to Batavia.

Iowa, Plymouth—The Iowa Heat, Light and Power Co., of Grinnell, has purchased a site and plans to build a power station to supply electricity in Plymouth. C. H. Utter, Grinnell, Mgr.

Kan., Altoona—City voted $30,000 bonds to enlarge its electric-light and water system.

Kan., Grenola—City plans to hold election to vote on $15,000 bonds to improve the electric-light plant. W. B. Rollins & Co., 209 Railway Exchange Bldg., Kansas City, Mo., Engrs.

Mass., Worcester—The New England Power Co., 18 Grafton St., plans to spend $7,000,000 to extend its plant. A hydro-electric station of 22,000-kw. capacity probably will be constructed in the upper Deerfield Valley, Vermont, it being possible to secure about 300-ft. operating head at that site. A. E. Pope, Ch. Engr.

Minn., Colerine—The Minnesota Utility Co. plans to build a substation.

Mo., Sedalia—The City Light and Traction Co., East Broadway, plans to improve its plant. Estimated cost, $60,000.

N. J., Newark—The Tanners' Leather Co. plans to build a 1-story power house addition to its plant at 390 Frelinghuysen Ave.

N. J., Newton—The Borough Committee plans to install an electric street-lighting system to replace the present gasoline lamps. Negotiations for the improvement are under way with the Newton Gas and Electric Co.

N. J., Stratford—The Lighting Commission of the Township Committee plans to rebuild, improve and extend the local street-lighting system and to award a 5-year contract in connection with the work.

N. Y., Lockport—The United Paper Board Co. plans to build a 1-story, 100 x 100-ft. power house. S. Mitchell, 171 Madison Ave., New York, Pres.

N. Y., Syracuse—The Syracuse Lighting Co., 339 South Warren St., plans to furnish power and lighting service at the new military camp on the Van Vleck Rd. The company also plans to extend its transmission system to that point and build a local lighting system. Estimated cost, $20,000. J. A. Pearson, Philadelphia, Pur. Agt.

Ohio, Dayton—The Dayton Metal Products Co., Taylor St., plans to build a power plant. Estimated cost, $250,000. H. E. Talbott, Pres.

Okla., Alva—The Alva Power Co. plans to increase the capacity of its plant and remodel and equip same with modern machinery.

Penn., Philadelphia—H. Belfield Co. has purchased a site on the northwest corner of 19th and Cambria Sts. and is having plans prepared by W. Steele Co., Arch., 1600 Arch St., for a combined power plant and garage.

S. D., Miller—City plans election to vote on $75,000 bonds to build a 300-hp. steam power and central heating plant, also rebuilding the entire distributing system and installing heating feeders and extension of sewer system. Address City Light and Power Co., W. Saltman, Mgr.

Tex., Port Lavaca—Calhoun County Court plans to grant franchise to install electric-light plant.

Utah, Richfield—The Southern Utah Power Co. has been granted a permit by the State Public Utilities Comn. to build extensions to its plant. The plans include a 100-hp. generator on Panguitch Creek and a distributing system for the Town of Panguitch; transmission line from Sevier to the latter town, with a distributing system in Marsville, also transmission line to the Deer Trail Mine to transmit 300 hp. C. I. Berkholder, Charlotte, N. C., Mgr.

Wash., Tacoma—The Chicago, Milwaukee & St. Paul Ry., Ry. Exchange Blk., Chicago, is having plans prepared for a large substation to furnish energy for the Tacoma yards and for the division between this city and Seattle. A. M. Ingersoll, Tacoma, Asst. to Vice Pres.

Wis., Racine—The Racine Rubber Co. is making surveys to enlarge its steam generating plant. Estimated cost, $75,000. A. Carlson, Engr.-in-Charge.

Wis., Sheboygan—The Eastern Wisconsin Electric Co., main offices at Grand Rapids, has retained the Fargo Engineering Co., Consumers Bldg., Jackson, Mich., to prepare plans for a 1-story, 60 x 90-ft. addition to its steam power plant.

B. C., New Westminster—City Council granted permission to the Western Power Co. of Canada to run a power line from 3rd Ave. and 11th St. down 3rd Ave. and across to Poplar Island to serve the shipbuilding plant of the Westminster Construction and Engineering Co. L. B. Philpot, Vancouver, Supt.